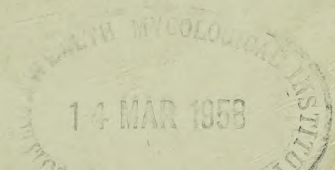
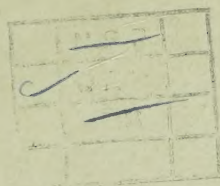


ANNUAL REPORT
of the
WEST AFRICAN
COCOA RESEARCH
INSTITUTE

1956-57



A POISONOUS INSECTICIDAL
SOLUTION HAS BEEN USED
IN BINDING THIS BOOK.



Capsid control with a mist blower

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WEST AFRICAN
COCOA RESEARCH
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1956-57

Price 5/-

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MANAGING COMMITTEE

At 31st March 1957

CHAIRMAN

- *Chief Secretary, West African Inter-Territorial Secretariat.

MEMBERS

- *†Director, West African Cocoa Research Institute.
Chairman, Ghana Cocoa Marketing Board.
Mr B. E. Dwira, member of the Ghana Cocoa Marketing Board.
Mr J. H. Asafu-Adjaye, Ghana.
- *Principal Assistant Secretary, Ministry of Agriculture, Ghana.
- *†Director of Agriculture, Ghana.
Permanent Secretary, Ministry of Research and Information,
Federation of Nigeria.
- †Director of Agricultural Research, Federation of Nigeria.
Permanent Secretary, Ministry of Agriculture and Natural
Resources, Western Region, Nigeria.
- †Director of Agriculture, Western Region, Nigeria.
Rev. E. T. Latunde, O.B.E., Nigeria.
- †Director of Agriculture, Sierra Leone.

CO-OPTED MEMBERS (non-voting)

- †Director of Agriculture, Eastern Region, Nigeria.
- †Deputy Director of Agriculture (Cocoa Industry), Ghana.
- †Principal Agricultural Officer, Southern Cameroons.
- †Secretary for West African Agricultural and Forestry Research.
Mr W. R. Feaver, Manager, Messrs Cadbury & Fry, Ghana.
Mr R. J. Smith, Manager, Messrs Rowntree-Fry-Cadbury, Nigeria.
- †Deputy Director, West African Cocoa Research Institute.
Secretary, West African Cocoa Research Institute.

* Members of General Purposes Sub-Committee.

† Members of Technical Sub-Committee.

SENIOR STAFF

At 31st March 1957

TAFO STATION

DIRECTOR	.. J. Lamb, O.B.E., M.SC., F.R.I.C., A.I.C.T.A.
DEPUTY DIRECTOR ..	.. *C. G. Johnson, PH.D., D.SC., F.R.E.S., M.INST.BIOL.
SCIENTIFIC ASSISTANT TO	
DIRECTOR	.. G. A. Jones, B.SC.
SECRETARY	.. H. L. Pugh, A.C.C.S.
OFFICE ASSISTANT/LIBRARIAN	Miss A. Bryan
ENTOMOLOGISTS	.. *C. G. Johnson D. J. Taylor, B.SC., DIP.AG.SCI., D.T.A. P. F. Entwistle, B.SC., A.R.C.S. Mrs Helen M. Entwistle, M.SC. A.R.C.S., (Temporary)
PLANT PATHOLOGISTS ..	.. W. T. Dale, M.SC., A.I.C.T.A. A. L. Wharton, B.SC., DIP.AG.SCI., D.T.A. G. Usher, B.SC., DIP.AG.SCI., D.T.A. A. Attafuah (Assistant Specialist)
BOTANISTS	.. A. D. McKelvie, B.SC., DIP.AG.SCI., D.T.A. R. G. Hurd, B.SC., PH.D.
PLANT BREEDER	.. D. R. Glendinning, B.SC.
CHEMISTS	.. T. A. Rohan, B.SC., PH.D., F.R.I.C. *Miss E. Margaret Holden, B.SC. *P. W. Arnold, M.A., B.SC., PH.D. R. K. Cunningham, B.SC.
AGRONOMIST	.. R. J. Benstead, N.D.A., C.D.A.
PLANTATIONS MANAGER ..	.. H. W. S. Allison
GUIDE-DEMONSTRATOR ..	.. F. E. Decker
STATION MANAGER ..	.. S. E. Ntim-Kwafo

IBADAN SUB-STATION

ENTOMOLOGIST	.. R. G. Donald, B.SC., A.I.C.T.A. (Acting Officer-in-Charge)
PATHOLOGIST	.. J. M. Thresh, B.SC., A.R.C.S.

* Seconded from Rothamsted Experimental Station.

ADMINISTRATION

MANAGING COMMITTEE

Two meetings of the Managing Committee were held during the year, one at Ibadan on the 16th August 1956, and the other at Tafo on the 28th March 1957. The Technical Sub-Committee met on the 14th August 1956, and on the 27th March 1957.

During the year legislation was enacted to enable Sierra Leone to participate in the work of the Institute and Mr J. W. D. Goodban, Director of Agriculture, was nominated as the Sierra Leone representative on the Managing Committee. Mr Imoru Egala replaced Mr F. R. Kankam-Boadu as Chairman of the Ghana Cocoa Marketing Board and attended the meeting of the Managing Committee held at Tafo as one of the Board's two representatives. The Permanent Secretary, Ministry of Agriculture and Natural Resources, Western Region, Nigeria and The Reverend E. T. Latunde, O.B.E., were nominated to serve as Nigerian members of the Managing Committee.

FINANCE

The Managing Committee has decided that the Institute's accounting system should be re-organised to conform to commercial accounting practice. A qualified accountant will be appointed to introduce the new system and to train an African officer, who, it is hoped, may eventually be able to take charge of the Institute's accounts.

The Balance Sheet as at 31st March 1957 is shown on page 92.

STAFF

Senior Staff

There has been a notable improvement in the senior staff position during the year. In addition to the new appointments detailed in this report, a further six officers are expected to join the Institute in the near future, while two Agronomists, an Entomologist and a Plant Pathologist are in training in the United Kingdom. One result of these developments will be a substantial increase in the staff at the Ibadan Sub-station.

At Tafo, Dr C. G. Johnson arrived in December on secondment from Rothamsted Experimental Station for one tour as Deputy Director, and Head of the Entomology Division. Dr Johnson acted as Director while Mr Lamb was on leave. Mr G. A. Jones took up his appointment as Scientific Assistant to the Director in January. Dr P. W. Arnold, who has been seconded from Rothamsted Experimental Station for twelve months to work on cacao nutrition, arrived

in May and was joined by Mr R. K. Cunningham, the new Soil Chemist, in November. Cacao breeding has been taken over by Mr D. R. Glendinning, and Dr R. G. Hurd has joined the Institute as Plant Physiologist.

The Acting Secretary, Mr R. J. Webb, who was seconded by the Crown Agents pending a permanent appointment, returned to the United Kingdom when Mr H. L. Pugh assumed duties as Secretary during July. Miss A. Bryan took up her appointment as Office Assistant Librarian in August, and in the same month Mr H. W. S. Allison arrived to take over the management of the cacao plantations.

Dr F. Raw returned to his substantive post at Rothamsted Experimental Station in June, 1956. Mr W. T. Dale, who has been Head of the Pathology Division since 1953, and Mr G. Usher have resigned.

Two Ghanaian students have been awarded WACRI post-graduate scholarships. Mr E. J. A. Asomaning, a graduate of Iowa University, USA, has been granted a scholarship to study plant physiology at Yale University, and Mr V. Ammah-Attoh has received an award to study entomology at the Imperial College Field Station in England.

Junior Staff

The junior staff position has remained relatively stable, with only two new appointments and one resignation, all in the Technical Assistant grades.

All routine field operations have been put under the control of the Plantations Manager, and he is now in charge of the labour force. The number of daily-rated employees has been reduced slightly to about 650.

Health

A survey of filarial infections in the Tafo area by Dr B. O. L. Duke of the Helminthiasis Research Unit, British Cameroons, has revealed a high incidence of a non-pathogenic skin-inhabiting nematode in the local population. This organism is transmitted by *Calimides grahami*, a common species of 'sand fly' in the area. In the course of general investigations on entomological aspects of personnel health Mrs H. M. Entwistle has examined a large number of flies, and estimates that approximately 0.1% are infective. It is hoped that localised insecticidal treatment of the main breeding sites will considerably reduce this nuisance.

PUBLICATIONS

The following papers, giving accounts of work done at the Institute, have been published during the year.

Archibald, J. F. and McKelvie, A. D.: 'The polythene sheet method'. Addendum to *WACRI Technical Bulletin* No. 3, 'The propagation of cacao by cuttings'.

Donald, R. G.: 'The natural enemies of some Pseudococcidae in the Gold Coast'. *J. W. Afr. Sci. Ass.*, **2**, pp. 48-60, 1956.

Knight, R.: 'Induced polyploidy in *Theobroma cacao* L. and related species'. *J. hort. Sci.*, **32**, pp. 1-8, 1957.

McKelvie, A. D.: 'Cherelle wilt of cacao. 1. Pod development and its relation to wilt'. *J. exp. Bot.*, **7**, pp. 252-263, 1956.

A paper by Miss E. Margaret Holden entitled 'An investigation on polyphenolic compounds of the cacao leaf in connexion with a chemical method for detecting virus infection' has been accepted for publication in the *Journal of the Science of Food and Agriculture* and will appear shortly.

SYMPOSIUM ON CACAO BREEDING

A symposium on cacao breeding was held at Tafo during October 1956, under the chairmanship of Dr G. D. H. Bell, Director of the Plant Breeding Institute, Cambridge. It was attended by Mr H. H. Croucher (Director of Agriculture, Western Region, Nigeria), Dr J. M. Waterston (Director of Agricultural Research, Federation of Nigeria), Dr W. R. Stanton (Maize Research Unit, Ibadan), Mr H. H. Rogers (PBI, Cambridge), Dr Walter Carter (Pineapple Research Institute, Hawaii), Mr F. W. Cope (Senior Plant Breeder (Cocoa), ICTA, Trinidad), Dr G. R. Howat and Dr B. D. Powell (Messrs Cadbury Brothers), Messrs A. E. Moss, P. S. Hammond, P. S. Castle and J. Bowden of the Ghana Department of Agriculture, and all the members of the senior staff at Tafo.

The first session was concerned with breeding for disease resistance with particular reference to swollen shoot disease. Mr W. T. Dale summarised the available information about resistance and tolerance to swollen-shoot virus and Mr A. L. Wharton gave a short paper on resistance to black-pod disease. At the second session Mr A. D. McKelvie described the breeding material at WACRI and afterwards a visit was made to the 8th and 9th Progeny Trials Areas. Mr D. R. Glendinning gave a paper at the third session on 'Techniques of breeding: experimental considerations' and a paper by Mrs P. F. Entwistle on 'Pollination of cacao' was read. At the fourth session a discussion on agricultural requirements as breeding characters was opened by Mr H. H. Rogers. Manufacturers' requirements were considered at the final session with Dr G. R. Howat giving the opening paper.

A full account of the proceedings has been prepared for publication.

VISITORS

During the year the Institute has been honoured by visits from His Excellency the Governor-General of Ghana; Sir Gordon Hadow, then officer Administering the Government; the Prime Minister; the Minister for Agriculture; and the Minister for Trade and Labour. Their Excellencies the Governor-General of the Federation of Nigeria, the Governor-General of the Spanish Territories of the Gulf of Guinea, and the Governor of Dahomey have visited the Ibadan Sub-station.

At the invitation of the Director a number of overseas scientists have visited Tafo to advise on various aspects of the research programme. Cacao breeding has been reviewed by Dr G. D. H. Bell, Director of the Plant Breeding Institute at Cambridge, and Mr H. H. Rogers, a former plant breeder at WACRI. A symposium on breeding problems was arranged during their visit, and an account of the proceedings, together with a report by Dr Bell and Mr Rogers on the Institute's breeding programme will be published shortly. Dr W. Carter of the Pineapple Research Institute, Hawaii, who was a member of the 1948 Commission of Enquiry into the Swollen Shoot Disease of Cacao in the Gold Coast, spent three months at Tafo evaluating the work of the Entomology Division, and has recommended many new lines of research. In particular the experiments on ant control with dieldrin, and the field testing of various chlorinated hydrocarbon insecticides for capsid control, were initiated during Dr Carter's visit.

Dr G. R. Howat, Dr B. D. Powell and Mr G. A. R. Wood have again visited Tafo to carry out experiments on fermentation and drying methods. Mr F. W. Cope, Senior Plant Breeder (Cocoa), ICTA, Trinidad, spent some weeks at the Institute studying the incompatibility mechanism in Upper-Amazon cacao. Mr C. S. Wishart of Messrs Plant Protection Limited worked at the Ibadan Sub-station for several months assisting with the experiments on the chemical control of capsids.

Other visitors have included the Chairman and the General Manager of the Ghana Cocoa Marketing Board; Mr Elysio Nunes, Director of the Cocoa Institute of Bahia, Brazil; Sir William Slater, Secretary of the Agricultural Research Council, England; Mr D. Rhind, Secretary for Agricultural Research, Colonial Office; the Honourable J. W. Cooper and the Honourable J. P. McRae from Liberia; and delegates to the Independence Celebrations from Russia, West Germany, Holland, Yugoslavia, Ceylon, Libya and the Belgian Congo. Several visits have been received from senior officers of other West African research organisations, and the Departments of

Agriculture of Ghana, Nigeria and Sierra Leone, and the Institute has maintained close contact with the University Colleges of Ghana and Ibadan.

STATION MANAGEMENT AND MAINTENANCE

Buildings

The new laboratory block at Ibadan has now been completed and was occupied at the beginning of the year. At Tafo work has started on clearing sites for six new bungalows which are to be constructed in the Residential Area. Routine maintenance has been carried out on all roads and buildings.

Water supplies

As a result of the prolonged harmattan season the mean daily consumption of water reached a peak of 26,819 gallons in March 1957, the highest figure yet recorded at the waterworks. There were, however, no difficulties in maintaining a continuous supply of potable water to meet the demand. Daily production varied between 19,705 gallons in June 1956, and 32,279 gallons in March 1957. The rainfall recorded at the waterworks varied from 0.80 in. in August to 9.47 in. in April, with a total for the period under review of 45.0 in., on 132 wet days.

Production of vegetables

A supply of green vegetables, rice, maize, and Chinese yams has been maintained throughout the year.

COCOA PRODUCTION

Tafo Station

A total of 81,721 lb. of cocoa has been sold during the year, representing an increase of 24,348 lb., or 42.4 per cent., over the figure for the previous year. On the recorded plots of the Old Station the yield of dry cocoa per acre was 32 per cent. higher than in the 1955-56 season. Details of this year's crop on the recorded areas are given in Table 1, and a comparison with previous yield data in Table 2. In the latter bean weights include estimated yields from pods used for experimental purposes.

Weekly harvesting was carried out on a strict schedule and only 3.3 per cent. of the total pods harvested were discarded as unfit for fermentation, compared with 7.8 per cent. last year. Another contributory factor to the lower percentage of discarded pods may have

TABLE I
Yield of recorded plots, Old Station*

Date of picking	Harvested	Total pods Discarded	% Pods discarded	Pods fermented	Wet wt. of beans (lb.)	Dry wt. of beans (lb.)	% Dry to wet weight	Pods per lb. dry cocoa	Pods issued for expts.
1956									
June 5-8	1,365	57	4.2	1,308	278.1	106.44	38.27	12.3	—
" 12-14	1,494	50	3.3	1,444	331.6	137.70	41.53	10.5	—
" 18-21	2,298	50	2.2	2,248	541.5	206.30	38.10	10.9	—
" 25-28	2,289	68	3.0	2,221	515.0	196.71	38.20	11.3	—
July 2-4	2,419	79	3.3	2,340	545.9	216.50	39.66	10.8	—
" 9-11	2,081	104	5.0	1,977	436.4	179.92	41.04	11.0	—
" 16-19	1,716	96	5.6	1,620	367.1	153.16	41.72	10.6	—
" 23-25	2,136	87	4.1	2,049	490.5	203.95	41.58	10.0	—
" 30-Aug. 1	3,013	121	4.0	2,892	686.5	284.71	41.84	10.2	—
Total Minor Crop	18,811	712	3.8	18,099	4,188.6	1,685.39	40.24	10.7	—
Aug. 20-22	8,834	314	3.6	8,520	2,025.0	878.21	43.37	9.7	—
Sept. 3-7	16,584	754	4.5	15,830	3,608.4	1,561.66	43.28	10.0	250
" 10-14	16,419	754	4.6	15,615	3,538.0	1,487.02	42.03	10.4	250
" 17-21	21,421	841	3.9	20,527	4,621.9	2,026.77	43.85	10.0	250
" 24-28	34,055	1,118	3.3	32,687	7,320.6	2,918.80	40.28	11.1	250
Oct. 1-5	21,557	564	2.6	20,743	4,673.5	2,096.48	44.86	9.9	250
" 8-12	24,254	576	2.4	23,428	5,942.3	2,219.41	44.02	10.6	250
" 15-19	22,496	328	1.5	21,661	4,497.9	1,819.82	40.46	11.6	907
" 22-26	26,386	758	2.9	24,374	5,259.2	2,217.79	42.74	11.1	954
Nov. 5-9	28,446	777	2.7	26,869	5,395.4	2,235.24	41.43	12.0	800
" 12-16	27,556	825	3.0	25,785	5,335.9	2,327.60	44.45	11.1	946
" 21-26	28,095	608	2.2	22,997	4,751.1	2,037.68	42.89	11.3	4,490
Dec. 3-7	29,220	766	2.6	27,846	5,830.8	2,507.98	43.01	11.1	608
" 10-14	29,946	773	2.6	28,021	5,883.9	2,487.70	42.28	11.3	1,152
" 17-28	20,455	596	2.9	19,291	4,175.3	1,814.19	43.45	10.6	568
1957	15,939	675	4.2	15,264	3,218.4	1,299.32	40.00	11.7	—
Jan. 2-11	23,856	1,211	5.1	22,645	4,665.5	1,933.88	41.45	11.7	—
" 14-18	5,318	818	15.4	4,500	897.8	360.95	40.20	12.5	—
Total Main Crop	401,037	13,259	3.3	375,853	80,670.9	34,290.50	42.51	11.0	11,925
1956-57	419,848	13,971	3.3	393,952	84,859.5	35,975.89	42.39	11.0	11,925
1955-56	323,714	25,096	7.8	292,824	66,167.0	27,501.63	41.70	10.6	5,794

been a reduced incidence of black-pod disease as a result of the drier season.

A higher recovery rate during fermentation and drying has more than compensated for the lower average pod size.

TABLE 2
*Comparative yield data from recorded plots, Old Station**

		Pods harvested	Percentage pods discarded	Total wet weight of beans (lb.)	% Dry to wet weight	Pods per lb. dry cocoa	Yield per acre
1956-57	..	419,848	3.3	86,847	42.67	11.0	581.9
1955-56	..	323,714	7.8	67,326	41.70	10.6	440.8
19-year mean		514,594	11.0	95,437	41.30	11.4	614.5

* 63.69 acres of Amelonado cacao.

Yield distribution in recorded quarter-acre plots is shown in Table 3. The mode has moved to the 601-800 lb. per acre class.

TABLE 3
Distribution of yield between quarter-acre plots

Yield class				Percentage of plots in each class			
				1953-54	1954-55	1955-56	1956-57
0- 200	..	..	..	11.61	17.85	12.5	7.6
201- 400	..	..	..	30.80	39.29	32.6	23.2
401- 600	..	..	..	30.36	30.36	33.9	25.4
601- 800	..	..	..	17.86	10.27	15.2	26.8
801-1,000	..	..	..	8.48	1.79	5.4	10.3
1,001-1,200	..	..	..	0.89	0.44	0.4	6.3
1,201-1,400	..	..	..	—	—	—	0.4
Highest plot yield (lb. per acre)				1,171.84	1,104.96	1,058.40	1,274.40
Lowest " " " " "				nil	nil	nil	8.00

Out-Stations

The five out-stations at Adonkwanta, Akwadum, Nankese, Kukua and Koransang were transferred to the Department of Agriculture during the year.

Seed Distribution

A total of 20,628 F3 Upper-Amazon pods were sent to Nigeria as seed.

Swollen-Shoot Disease Incidence

The incidence of disease on the Old Station increased slightly during the year. Five hundred and ninety-two infected trees and twenty-three suspects were cut out, representing 2.97 per cent. and 0.11 per

cent. of the tree population at the beginning of the year. Comparative figures for the previous year were 1.91 per cent. and 0.04 per cent. respectively. In addition 283 diseased young trees were found in the replanted areas.

On the Square Mile 3,087 trees were removed in the course of routine swollen-shoot control operations. This figure comprises 2,200 positive and 200 suspected infections, and 687 contact trees. In the experimental areas controlled by the Agronomy Division thirty-six young trees have shown symptoms of swollen-shoot disease.

WEATHER SUMMARY

Tafo Station

Figures for 1956 compared with 19-year means

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Highest Shade Maximum	91.4	93.7	93.1	93.7	92.2	89.1	87.0	86.4	88.1	89.8	90.4	90.6
1956	..	90	93	95	91	89	89	87	90	91	89	91
Lowest Shade Minimum	59.3	61.8	65.9	64.4	68.8	66.0	65.9	65.1	66.8	66.8	65.5	62.3
1956	..	59	67	68	68	61	65	64	67	68	67	64
Mean Relative Humidity	88.5	83.8	82.1	80.9	81.7	84.9	86.0	86.0	85.2	83.4	81.2	84.2
1956	..	91.7	83.5	81.3	82.5	84.2	84.0	84.0	83.6	82.7	82.7	84.4
Mean Relative Humidity	55.7	53.0	56.6	59.2	64.0	69.5	70.2	69.5	71.0	71.0	65.8	61.7
1956	..	61.5	57.4	58.6	68.1	67.8	73.9	68.7	67.6	71.2	71.1	63.0
Rainfall in inches	1.54	3.66	6.08	5.81	7.02	8.36	5.23	2.52	6.17	9.09	4.14	2.36
1956	..	0.89	6.40	8.57	8.57	5.12	1.01	0.69	4.68	6.33	5.56	2.69
Number of Wet Days	3.5	7.0	11.8	11.1	13.8	18.6	13.6	12.8	14.6	18.6	10.8	6.1
1956	..	2	3	9	16	19	9	10	14	21	14	7

Annual Rainfall figures (in inches) 1938-1956

	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	19-Year Mean
	55.33	84.96	56.92	56.59	59.45	69.09	49.12	68.87	47.03	67.30	66.99	71.81	63.47	66.23	65.77	53.88	57.53	73.16	51.12	61.98

Monthly Rainfall (in inches) and Number of Wet Days, April 1956-March 1957

Month	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March
Rainfall in inches	8.57	8.57	5.12	1.01	0.69	4.68	6.33	5.56	2.69	1.28	2.81	1.48
Number of Wet Days	9	16	19	9	10	14	21	14	7	5	6	9

RESEARCH

In the **Plant Pathology** Division the work on resistance and tolerance to swollen-shoot disease has been expanded. No evidence of marked resistance has yet been obtained and there is little to suggest that resistance and tolerance are closely correlated. From experiments on seedlings showing only sporadic symptoms it seems that highly tolerant plants contain very little available virus. If confirmed by further tests now in progress, this may have important practical implications in the use of tolerance as a control measure. In Nigeria, work on coppicing has led to the adoption of a more economical cutting-out procedure for the treatment of virus outbreaks. The survey of *Adansonia digitata* has been completed for all Ghana except northern Togoland, and the work on natural hosts of cacao viruses has now been considerably reduced. Experiments on the relative virulence of selected Ghanaian and Nigerian isolates towards Amelonado cacao have continued—preliminary results suggest that young seedlings can give a good indication of what is to be expected in mature trees.

In their third year the fungicidal spraying trials have confirmed the effectiveness of copper fungicides against black-pod disease, and have again shown the value of frequent harvesting as a control measure. These trials have now been terminated. Present work includes a detailed study of the frequency distribution of black-pod infections over a complete season, in relation to the number of fruits of all ages borne on the trees. Evidence of resistance to black-pod disease has been found in some cacao selections, and this is being followed up. For testing these selections a standard laboratory technique for inoculating unwounded pods is needed, and work has started on the development of suitable methods, with promising results. Comparative tests of isolates of *Phytophthora palmivora* from Ghana and Nigeria are being extended.

From preliminary field experiments carried out by the **Entomology** Division, in conjunction with the Department of Agriculture, it would appear that endrin, applied as a mistblown aqueous emulsion, may be particularly effective against capsids in mature cacao. In these tests *gamma*-BHC, aldrin and dieldrin were also satisfactorily effective, but heptachlor did not give adequate control. For ten weeks after routine capsid spraying with *gamma*-BHC there was a progressive decline in the numbers of pollinating midges visiting flowers, but no appreciable difference in pollination rates on treated and untreated plots. In Nigeria tests with *gamma*-BHC have shown that capsids can be efficiently controlled using ordinary knapsack sprayers. A series of trials has been started to investigate the effect of dieldrin

on ants attending mealybugs, and the effect of ant removal on the mealybug population, and hence on the spread of swollen shoot disease. On cacao sprayed with dieldrin mealybug populations fell to negligible proportions and continued at this low level five and a half months later.

In the experimental plots of the **Agronomy** Division the condition of the cacao has improved considerably. This can be attributed largely to the introduction of routine capsid control and to the reduction of shade on areas which were previously heavily shaded to minimise capsid damage. This cacao, planted from 1947 onwards, has now reached economic bearing age, and greatly increased yields have been recorded.

The **Botany** Division has planted further variety trials in Ghana and in Nigeria, to compare Upper-Amazon cacaos and various new hybrids. Similar trials already established in Ghana show Upper-Amazons to be growing more vigorously than Amelonado everywhere. Crosses between Upper-Amazon and West African types in the 8th Progeny Trial have continued to yield well and certain of those in the 9th Progeny Trial have now come into bearing.

The polythene sheet method for rooting cacao cuttings has been improved, and it has now been adopted for routine use at WACRI. Investigations on the physiology of fruiting have continued. The results suggest that, except in extreme cases, yield is largely independent of levels of flowering, pollination, setting or wilt, but depends rather on the nutritional reserves of the tree. Experiments have been started to study the nutrient requirements of cacao by growing seedlings in water culture. The uptake of phosphorus from the soil is being investigated using radioactive tracers.

During the year the **Chemistry** Division has initiated a series of major nutrient fertilizer trials on both Amelonado and Upper-Amazon cacao. The lack of uniformity in fermenting heaps of cocoa, demonstrated in the previous year's work, has been investigated in detail in this season's main crop. It has been found that beans in the top layer of the heap die much more quickly than those at the centre, and an acceptable product can be prepared from surface beans taken from the heap after only thirty hours. Experiments have been started to investigate the relationship between polyphenols, appearance of the cotyledons, and the quality of fermented and dried cocoa. The results of studies on cocoa enzymes suggest that the conditions in the fermenting mass during the comparatively short period after the death of the beans and before the enzymes are inactivated may be of considerable importance.

TAFO STATION

EXPERIMENTAL AREAS

A—Agronomic Investigations

- A 1—Upper-Amazon Seed Multiplication Plot.
- A 2—Upper-Amazon Spacing and Pruning Experiment.
- A 4—Transplanting Demonstration.
- A 5—*Herrania* Plot.
- A 6—Uniformity Trial, with young Amelonado cacao.
- A 7—Amelonado Source Experiment.
- A 8, 9—Seedling Reserves.
- A10—Establishment Experiment II—Comparison of Planted and Natural Shade.
- A11—Amelonado Spacing Experiment.
- A15—*Herrania* Bulking Area.
- A16—Transplanting Experiments I and II—Superphosphate and Reduction of Foliage.
- A17, 18, 20 to 22—Seedling Reserves.
- A23—Shade and Manurial Trial.

B—Botanical Investigations

- B 1—Clonal Collection.
- B 2—Clonal Trial III—1956.
- B 3—Progeny Trial IX—1954.
- B 5—Clonal Trial I—Gold Coast Selections.
Pod Disease Resistance Trial.
- B 6—Cytogenetics Observation Plot.
- B 7—Progeny Trial VIII—1952.
- B 8—Albino Plot.
- B 9—Clonal Trial II—Gold Coast Selections.
- B10—Trinidad Introductions Area.
- B11—*Theobroma* and *Herrania* spp. Area.

- B12—Progeny Trial II—1942.
- B15—Progeny Trial IV—1941-44.
- B16—Progeny Trial I—1940.
- B17—Colombian Introductions Area.
- B18—Proposed Progeny Trial Area.
- B19—Seedling Growth Experiment.
- B20—Plant Breeding Nursery.
- B21—Propagators.
- B22—Clonal Nursery.
- B23—Early Bearing Experiment.
- B24—New Planting Area.

E—Entomological Investigations

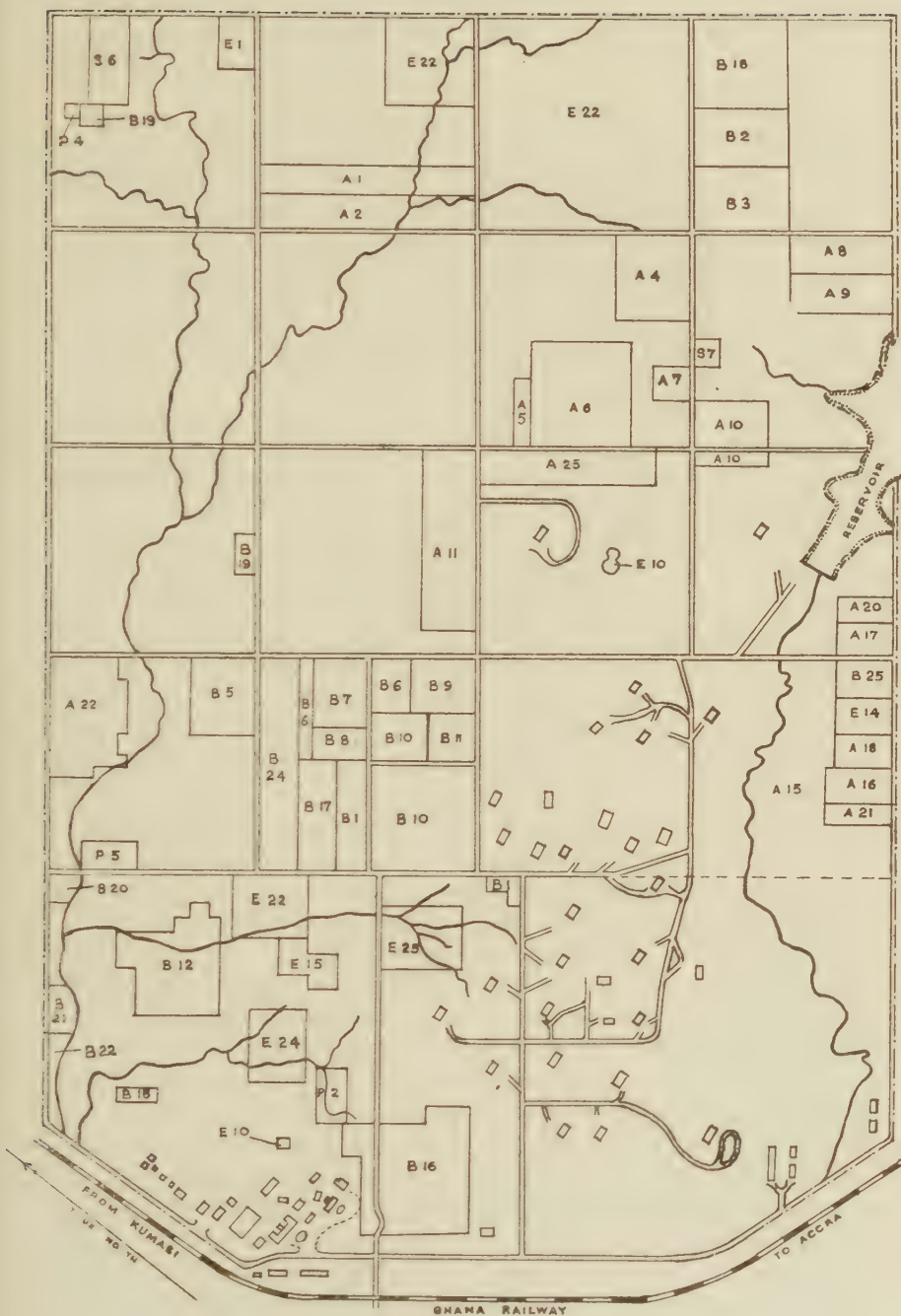
- E10—Light-trap for Capsids.
- E14—Capsid Control Experiment—Dusting and Pruning of Seedling Cacao.
- E15—Capsid Control Costing Trial—Dusting and Pruning Method.
- E22—Ant Control Experiment.
- E23 }
E24 } Effect of Insecticides on Pollination.
E25 }

S—Soil Science Investigations

- S 6—Establishment Experiment on Clear-felled land—different ground covers.
- S 7—Soil Exposure Experiments.

F—Fungus Investigations

- P 2—Studies on Susceptibility to Black-pod Disease.
- P 3—Swollen-shoot Alternative Hosts Nursery.
- P 4—Collection of material showing tolerance or resistance to Swollen-shoot Disease.



VIRUS RESEARCH

THE HOST RANGE OF CACAO VIRUSES (W. T. Dale and A. Attafuah)

Laboratory tests

Various previously reported hosts of cacao viruses have been experimentally infected (using mealybugs) with further isolates, and details of differential susceptibility will be published elsewhere (Tinsley & Wharton, in preparation). The following additional species, native to Ghana and related to cacao, have been infected:

BOMBACACEAE—*Bombax costatum* Pellegr. & Vuillet (a fairly common small tree in the Northern territories); MALVACEAE—*Hibiscus abelmoschus* L., *Hibiscus* sp. (a form of okra and probably *H. manihot* L. var. *caillei* A. Chev., but with bracteoles intermediate between this and *H. esculentus* L.—*fide* Herb. R.B.G., Kew).

B. costatum seedlings, when infected by New Juaben virus, developed leaf mosaic and soon died, probably because of the infection. All the local forms of *Ceiba* which have been tested (see *Ann. Rep. WACRI*, 1955-56, p. 28), and one from Indonesia, have proved susceptible to the same virus. *H. abelmoschus* was also infected by it but apparently not by Kpeve, while *H. ?manihot* has given evidence of susceptibility to the latter but not, so far, to New Juaben. The susceptibility of herbaceous or semi-herbaceous hosts of the Malvaceae and Tiliaceae (*loc. cit.*) is probably of no practical significance; they are not normally colonised by mealybugs and are relatively short-lived, while susceptible local species of the latter family are often quickly killed by infection.

Further observations are being made on the persistence of cacao viruses in alternative hosts. Bosumtwi was recovered from *Herrania balaensis* Preuss., without recourse to coppicing, thirty-six months after infection; virulent New Juaben from *Sterculia alata* after twenty-five; Kpeve from *Bombax buonopozense* P. Beauv. (? = *B. angulicarpum* Ulbrich) after nineteen; and Bosomuoso from *Theombroma angustifolia* DC. after eleven months. *Heliocarpus popayanensis* H.B.K. readily yielded Kpeve after eighteen months, but virulent New Juaben, Bosomuoso and Offa Igbo (Nigeria) were not recovered from it after comparable periods.

The following native plants in addition to those listed previously (*loc. cit.*) have not yet given evidence of susceptibility to cacao viruses:

MALVACEAE—*Hibiscus asper* Hook. f., *H. congestiflorus* Hochr., *H. surattensis* L., *Sida linifolia* Cav., *S. urens* L.; BOMBACACEAE—*Grewia latifolia* Mast., *G. malacocarpa* Mast.. *H. congestiflorus*, *H. surattensis* and *S. urens* were tested against both Kpeve and New Juaben, the remainder against the latter alone.

Bombax buonopozense, *Ceiba pentandra* Gaertn. and *Theobroma bicolor* Humb. & Bonpl. are susceptible, like cacao, to virus isolates from baobab trees (*Adansonia digitata* L.).

The search for natural infections

Tests for virus infection (using mealybugs) have been made on nearly 200 more baobabs, all in Trans-Volta/Togoland or the eastern part of the Northern Territories. Material for testing was usually taken only from very old trees or those showing one or more of the following symptoms, considered suggestive of virus infection: mottling, chlorotic flecking, curling or reduction in size of leaves; excessive proliferation of shoots on the trunk; gnarled main branches often terminating rather abruptly in thin shoots (though not obviously cut back), and poor growth without any obvious cause. As nearly all the samples were collected in dry weather, during the latter part of January and February, and were in many instances leafless cuttings which have yet to produce leaves for testing, final results are not available. However, virus from one tree at Agboleve, a few miles east of Kpeve, has already been transmitted to cacao seedlings. Collections of leaves showing very suspicious patterns were made from baobabs at Mile 102 on the Accra-Denu road (between Afife and Agbosome) in the Trans-Volta area, and at Ho in southern Togoland.

Present information on the distribution of virus infection amongst baobabs lends little support to the suggestion (*Ann. Rep. WACRI*, 1954-55, p. 32) that it came into Ghana from the north. Nor does the infection, by vectors, of seeds in broken pods appear to be a feasible means of dissemination; mealybugs placed on mature seeds seem unable to penetrate the very hard testa, though they may feed on the surrounding pulp. As regards the possible origin of Ghanaian cacao viruses, only isolates of the very distinctive Kpeve type show affinities with those from baobabs. Infection in baobabs almost certainly antedates that in cacao, but it may have spread to them from some other host, perhaps a highly tolerant and virtually symptomless one. Several possible carriers occur where infected baobabs are found, the shorter hybrid *Ceiba* (*Ann. Rep. WACRI*, 1955-56, p. 28) being particularly common in southern Togoland. Although baobabs are the most likely immediate source of Kpeve-type infection in cacao (judging by the ease with which mealybugs can experimentally transmit it between the two hosts) some outbreaks may have originated otherwise. No baobabs were seen in the immediate vicinity of the outbreaks at Goviefe Todzi and Kpandu, but *Bombax buonopozense* and *Ceiba* were both present.

The surveying of trees other than the baobab for natural infection with viruses transmissible to cacao has now been virtually suspended. The following species have been tested during the past two years, in the numbers indicated: *Sterculia rhinopetala* K. Schum. (198), *S. tragacantha* Lindl. (127), *Ceiba pentandra* (61), *Cola gigantea* var. *glabrescens* Brennan & Keay (21), *Hildegardia barteri* (Mast.) Kosterm. (19) and *Bombax buonopozense* (5). Apart from the one already recorded in *C. pentandra* (*loc. cit.*, p. 29) no infections were diagnosed. These negative results may not mean that all the tested trees were healthy, because even in artificially infected saplings of these species virus availability soon falls to a very low level.

INSECT-TRANSMISSION STUDIES (W. T. Dale)

The effect of source-feeding period

Further attempts to transmit the New Juaben virus with nymphs or young adults of *Pseudococcus njalensis* Laing given one hour or less on young infected plants were unsuccessful. Two small-scale experiments to find out whether source feeds of more than twenty-four hours result in reduced infectivity, regarding which previous evidence is conflicting (*Ann. Rep. WACRI*, 1954-55, p. 34), gave no support to this suggestion. In the first experiment, young adults were given access to infected plants for one, two or three days, and those found feeding were immediately transferred to indicator plants (as dissected cacao beans) at the rate of one per bean. Matters were so arranged that all the insects were transferred at approximately the same time on the same day. The respective transmission rates were 50, 55 and 43 per cent. The second experiment, carried out concurrently with the first, was identical, except that nymphs were used. Those given one or two days' access to the source plants each infected one third of the indicator beans, but too few were found feeding after three days to give a valid comparison.

The importance of vector age

It might be inferred from the above results that young adults are slightly more efficient vectors than nymphs, but the difference is probably not a real one (see *Ann. Rep. WACRI*, 1954-55, p. 35; 1955-56, p. 30). In a further experiment, again using one insect per indicator bean, the former gave 57 and the latter 54 per cent. transmission.

Cornwell (*Ann. Rep. WACRI*, 1955-56, p. 38) has shown that over 90 per cent. of mobile mealybugs (*Pseudococcus njalensis*) are first-instar nymphs and less than 2 per cent. are adults. Interest therefore centres on whether the former acquire virus from infective parents, or by feeding before or during their early migrations.

Nymphs removed at birth from adults colonising young Amelonado seedlings infected with New Juaben, produced no infections when transferred to sixty-six indicator beans at the rate of ten per bean. There was thus no evidence of transmission from infective parents to their progeny, which is not surprising in view of the short period the virus is known to persist in the feeding mealybug (Posnette & Robertson, *Ann. appl. Biol.*, **37**, p. 363, 1950). In a second experiment, gravid females were placed for twenty-four hours in comparable young seedlings infected with the same isolate. The nymphs produced were then transferred singly to indicator beans 0, 24, or 48 hours after the removal of their parents, separate source plants being allocated to each treatment to avoid undue disturbance of feeding insects. Of 107 nymphs 0·1 days old on or near the source plant, only 12 appeared to be feeding at the time of their removal, and none transmitted infection. At 1–2 days old, 17 out of 47 of the insects appeared to be feeding, but transmission was effected only by four that were not. Obviously these had fed, and perhaps the 17 had not done so long enough to have a reasonable chance of acquiring virus. Twelve out of 25 nymphs 2–3 days old infected their indicator beans, and those apparently feeding seemed to be about as efficient as the remainder (8·17 transmissions as against 4/8). It is plain that the minute first-instar nymphs of *P. njalensis*, even when no more than 2–3 days old, are efficient vectors of New Juaben, and in view of their mobility and numerical preponderance they must play a major part in its natural spread. The main importance of adults lies in their production of nymphs.

Transmission of virus isolates by different vector species

Like *Pseudococcus njalensis*, *Planococcus citri* (Risso) is able to transmit baobab-virus isolates (AD7, 14, Wasipe, Wusuta) but *Ferrisia virgata* (Ckll.) has so far failed to do so (AD7, 14, 36, Wusuta). This failure represents a further similarity between baobab isolates and Kpeve or Alaparun (Nigeria) virus from cacao.

F. virgata has experimentally transmitted two Western Province cacao-virus isolates (Aiyiboso and Amafie), and *Pseudococcus* sp. (near *gahani* Green) Bosomuoso from the same area. The former mealybug is also a vector of Sedi Nkawie and Ankrankwanta from Ashanti. In the past, New Juaben and Kpeve have been occasionally transmitted by *Dysmicoccus brevipes* (Ckll.) from pineapples, though these insects could not be permanently established on cacao. More recently, specimens from groundnuts, which probably harbour a distinct strain of this mealybug, failed to transmit in tests with the former virus. *P. njalensis* has proved to be a vector of isolates from Osino in the Eastern Province and Worawora in Togoland (see below). The insect

has again failed to transmit in experiments with Asalu from Nigeria (see also Ibadan Sub-Station section of this Report, p. 72).

Transmission from cacao pods

Previous workers have reported transmission of cacao virus from pods, but no published record of the state of maturity of the pods is known to the writers. Because only ripe pods are normally transported and these are often colonised by mealybugs, it is important to know whether virus can be transmitted from them. It was considered that the senescent shells of ripe pods might contain little or no available virus, but this is not so; using ten nymphs of *Pseudococcus njalensis* per indicator bean, transmission rates of 8/11 and 4/8, respectively, were obtained from completely green and fully ripe pods from infected trees.

CLASSIFICATION AND COMPARISON OF ISOLATES

(A. Attafuah and W. T. Dale)

Identification of viruses in field outbreaks

Further material has been collected from cacao trees showing unusual virus symptoms, so that the isolates concerned may be studied in the laboratory. Most of these recent collections are from discrete outbreaks selected for the joint WACRI—Department of Agriculture experiments on swollen-shoot disease control (p. 47).

New Juaben is spreading into areas where other distinct isolates occur. This has happened at Mamfe, to the south, where some of the trees in one outbreak were found to be infected by both Mampong and virulent New Juaben. To the north, outbreaks of the latter are interspersed with others showing distinctive leaf symptoms and, in at least some instances, lacking swellings. Mild viruses of this type were already known from the vicinity of Osino, but may be present also around Kwabeng and at Fankyeneko near Bosuso. Avirulent infections also occur in the Nkawkaw area, but there is no reason to think, at present, that these differ appreciably from the isolate already described from there (Posnette, *Ann. appl. Biol.*, **34**, p. 38, 1947).

In August 1953, indicator plants were patch-grafted with material from a suspected outbreak at Worawora; three years later one was found to have two small swellings. It had been examined frequently for the first nine months after grafting but only occasionally thereafter, so it is possible that earlier symptoms were overlooked. When virus was transmitted from this plant to dissected beans, swellings appeared in the seedlings in less than three months, becoming large and numerous. The isolate resembles the one from Bisa (Manyá

Krobo), though the slight or transient leaf symptoms sometimes produced by that have not yet been observed with the one from Worawora.

Mild-strain protection as a control measure

It has been suggested that the breakdown of protection against virulent New Juaben observed in young uncoppiced Amelonado seedlings (*Ann. Rep. WACRI*, 1955-56, p. 31) may have resulted from giving the mild strain insufficient time to become fully systemic before challenging with the virulent one. Consequently, although this suggestion seemed unlikely, an attempt was made, using fifty nymphs of *Pseudococcus njalensis* per plant, to establish the virulent strain in five 27-month-old seedlings infected with a mild strain from the bean stage and giving no evidence of virulent infection, either by symptoms or transmission tests. After four months two of the plants began to show more virulent symptoms and, though the experiment is incomplete, mealybugs have transmitted virulent strains from them in addition to mild ones.

Protection as a criterion of relationship

Work on this project has been limited, and there have been no further results suggesting close relationship between isolates from widely separated outbreaks in cacao or other hosts. Asalu from Nigeria ('cacao necrosis virus'—see p. 72) gave no protection against Alaparun, Kpeve, virulent New Juaben, Nsaba (Eastern Province), four *Adansonia digitata* isolates (AD7, 36, 135 and Wusuta), or one from *Cola chlamydantha* K. Schum. (Anibil). Similarly, mild New Juaben did not interfere with the subsequent establishment of Nkawkaw, two isolates from *A. digitata* (AD7 and 14), or six from *C. Chlamydantha* (Aboboya, Achechere, Adiembra, Aiyim, Anibil and Bakokrom).

Symptomatology of isolates and their effect on growth

The hitherto unreported preliminary necrotic symptoms of Asalu were noticed virtually simultaneously at Tafo and Ibadan, in young graft-infected plants. Since it is unlikely that virus lines separated for several years would begin to produce the same new symptom at about the same time, the necrosis would seem to have been overlooked by previous workers, or attributed to some cause other than virus.

Observations on the relative virulence of selected Ghanaian and Nigerian isolates towards Amelonado cacao (*Ann. Rep. WACRI*, 1955-56, p. 32) are continuing in a replicated experiment. For each replicate, two of which have been completed, separate groups of five plants are infected (as dissected beans) with each isolate, a similar

group being left uninfected as a control. Records of symptoms and host growth are made during the life of the plants, and measurements taken after their removal at eight months old include the following: plant height; number of leaves present and shed; leaf products (length $\times$ breadth); fresh and dry weights of entire plants and their component parts (leaves, stem, tap-root, lateral absorbing roots).

Only a few general comments based on the first two replicates are made here, since it is proposed to prepare a full account when the experiment is complete. Virulent New Juaben reduced total dry weight to only 16 per cent. of that for healthy controls, and some plants died. Corresponding figures for the other isolates were Bosomuoso 28 per cent., Asijere (Nigeria) 30 per cent., Ilesha (Nigeria) 39 per cent., Kpeve 43 per cent., Aiyiboso 45 per cent., Offa Igbo (Nigeria) 52 per cent., Olanla (Nigeria) 62 per cent., Mampong 69 per cent., Bosumtwi (Ashanti) 73 per cent., Amafie 76 per cent., Wiasi (Western Province) and Bisa 81 per cent. There was reasonable agreement between the replicates; except for Kpeve, which rose from sixth in order of virulence in the first replicate to third in the second, no isolate changed its position by more than two places. Total fresh weights closely paralleled total dry weights for the various isolates, only the positions of Aiyiboso and Kpeve being reversed, due to a slightly subnormal water content in plants infected by the former in one replicate. Goodall (*Ann. appl. Biol.*, **36**, p. 440, 1949) found that virus infection decreased water content, but the present experiment has so far given no definite evidence of this. Leaf products (which are proportional to leaf areas) also followed much the same order as dry weights. Mean height and number of leaves per plant, present and shed, were more erratic, but agreed reasonably with the other data. Kpeve seems to owe much of its virulence to excessive defoliation, an average of over eighteen leaves per plant being lost. This figure exceeds even that for New Juaben (15). In plants infected by the latter, absorbing roots were almost non-existent (as reported by Goodall, *loc. cit.*). Bosomuoso and Asijere had a serious though less pronounced effect on the lateral roots. All the isolates except Kpeve produce swellings—on both stems and roots. Although final leaf patterns are sometimes distinctive, certain isolates can be distinguished only by following the complete sequence of symptoms.

Information on the virulence of some of these isolates in field outbreaks has been recorded in previous Annual Reports, and it would seem that young seedlings can give a good indication of what is to be expected in mature trees. Outbreaks in the Akwapim area afford a good comparison between virulent New Juaben and Mampong. The former is producing its usual lethal effect, but there is evidence that trees have survived infection with the latter for over twelve years.

Defoliation has occurred but some of the trees are bearing a reasonable crop. Some, if not all, cacao-virus isolates are complexes of related strains of differing virulence; Asijere, Kpeve and New Juaben have been already cited as examples (*Ann. Rep. WACRI*, 1955-56, p. 32). Although Asijere usually produces very severe symptoms, one indicator plant has shown no more than small swellings, leaf patterns being apparently absent; Kpeve-type isolates differ widely in the intensity of leaf symptoms and amount of defoliation they produce. Such variation can complicate the assessment of virulence. For example, an isolate at Tafo derived from the Ilesha outbreak, though obviously variable, usually produces much more severe symptoms than the immunologically related one from Olanla; but isolates from the same areas maintained at Ibadan have behaved in the reverse manner. Another Nigerian isolate studied at both stations, Elepo, gave a marked reaction at Tafo but had no perceptible effect on growth at Ibadan (*Ann. Rep. WACRI*, 1954-55, p. 95).

The possibility of host-induced changes

It seems likely that at least some cacao-virus isolates have a common origin, divergence having arisen through selective adaptation in different hosts. It would be of interest to demonstrate host-induced change or selection experimentally. Consequently, what was hoped to be a relatively uniform source of New Juaben was obtained in a young cacao seedling after passage through two similar plants, using single mealybugs (*Pseudococcus njalensis*). Virus from this source was then transferred to young plants of six susceptible species, including cacao. Since, serial passage within each host has been attempted but, owing to the resistance to infection shown by some species and difficulties of seed supply in certain instances, little progress has been possible. 'Back-tests' have been made at intervals to cacao plants, which are examined for any possible host-induced variation in symptoms. So far, no evidence of change has been observed, but the experiment will be continued indefinitely.

RESISTANCE AND TOLERANCE (W. T. Dale)

Experiments with New Juaben isolates

The third and fourth replicates of the experiment to compare resistance and tolerance to virulent New Juaben in fifty FI Iquitos-type (T17) seedling trees (*Ann. Rep. WACRI*, 1955-56, p. 37) are still not quite complete, due to a shortage of material suitable for cuttings. For every stand all five rooted cuttings became infected in at least one replicate, so there is no evidence of marked resistance. The use of fifty *Pseudococcus njalensis* nymphs per plant has proved to

be a mistake; greater differences might have been revealed by using smaller numbers. The following trees contributed virus-free plants in two or three replicates, in the numbers indicated: T17/1159 (1, 1, 1); 359, 448 (2, 1); 434, 1131, 1157, 2628 (1, 1). T17/1071 has contributed two uninfected plants in one replicate and three apparently so in another, but the results of 'back-tests' on the latter are still awaited, and treatment in a third replicate was carried out too recently for any assessment to be made. T17/2652 and 2655 have also given uninfected plants more than once, but again, final results are not yet available. All the stands mentioned merit further investigation with a view to possible use in breeding for resistance; although others have given up to five uninfected plants in single replicates, technical inconsistencies have doubtless been at least partially responsible. Hybrids with T17/434, 1131, 1157 or 1159 as one parent have previously given some indication of slight resistance (*Ann. Rep. WACRI*, 1954-55, p. 44; 1955-56, p. 37).

Cuttings in all four replicates were scored for tolerance, using the system already described (*loc. cit.*, p. 36), and mean scores have been calculated for each tree. T17/524 was the most consistently tolerant with a score of 2.85; next came 1071 (2.37), 2652 (2.07), 448 and 1220 (2.00 each). T17/448 may have a measure of resistance to infection associated with its tolerance (see above) and so may 1071 and 2652, though results for these are incomplete and should therefore be treated with reserve. Other possibly resistant stands had mean scores for tolerance as follows: 1159 (1.22), 359 (1.36), 434 (1.33), 1131 (1.33), 1157 (1.39), 2628 (1.67), 2655 (1.71). Trees T17/1855 (0.68), 1132 (0.75), 1856 (0.80) and 522 (0.85) showed little tolerance, though the first two each contributed an uninfected plant in one replicate. There is little to suggest that resistance and tolerance are closely correlated. Similarly, intensity of leaf symptoms and development of stem swellings do not seem closely associated. Though plants with stem swellings usually have large root swellings, this is not always so.

Uninfested 'twinned' seedlings (*loc. cit.*) corresponding to infested ones which remained apparently virus-free or showed varying degrees of tolerance have been used to provide rooted cuttings for further testing. Many of these tests have already been done (using twenty nymphs of *P. njalensis* per plant) but the results of 'back-tests' on symptomless cuttings are not yet available. It is hoped to ascertain how far the five plants which give no evidence of infection in the initial test are genuinely more resistant; at least one cutting each from four of them has already shown symptoms. The experiment may also provide more information on the association (or lack of it) between resistance and tolerance, and the extent to which the former

(like the latter) is subject to genetical segregation within T₁₇ progenies.

As already pointed out, dangers inherent in the use of tolerance as a control measure would be mitigated if reduced availability of virus to vectors proved to be associated with poorly developed symptoms. In an experiment using two-year-old Iquitos-type seedlings with symptoms of varying intensity (infected as dissected beans or 'twinned' seedlings in earlier trials, *loc. cit.*, pp. 35, 36) and one young adult of *P. njalensis* per indicator bean, the following transmission rates were obtained: severe, 38/215 (17.7 per cent.); intermediate, 30/282 (10.6 per cent.); regularly appearing mild symptoms, 21/145 (14.5 per cent.); very mild sporadic symptoms, 1/248 (0.4 per cent.). Plants in the first three categories gave very variable rates of transmission. For severely affected plants this is readily explainable, because only rather woody stem apices were sometimes available for mealybug feeding, and such tissues contain relatively little transmissible virus (Posnette & Robertson, *Ann. appl. Biol.*, **37**, p. 363, 1950). From the results obtained, it seems that highly tolerant plants contain very little available virus. If confirmed by similar tests, now in progress, this may have important practical implications.

An attempt has been made to obtain virus-free cuttings from tolerant infected plants, without recourse to heat or chemical treatment. Seven 'twinned' seedlings which had shown only mild transient symptoms were coppiced to give cuttings, of which between three and six per plant have been successfully rooted. Both the cuttings and regenerating growth on the stumps from which they were derived have been observed for symptoms, and transmission tests with vectors have been carried out on the former. At least one cutting from each plant has given evidence of infection, either by symptoms or positive transmission tests, though two of the plants themselves have shown no symptoms since coppicing. It appears that some of the cuttings, and perhaps even the two regenerating stumps, may be uninfected, which would imply that virus distribution at the time of coppicing was discontinuous. However, the unreliability of tests with vectors where highly tolerant material is concerned (see preceding paragraph) precludes the assumption that the object of the trial has been achieved, particularly since some cuttings which have shown symptoms have yet to give transmissions with vectors. Doubtful plants are being budded with Amelonado material, which should yield a definite answer in due course.

An attempt to produce virus-free budlings from four mildly affected Nanay-type trees (*loc. cit.*, p. 38) was unsuccessful, all the buds transmitting infection to the Amelonado stocks.

A complicating factor in tests for tolerance is the possibility of a

plant with mild symptoms having an avirulent strain of the virus. The fact that only seedlings with pronounced symptoms were used as sources of infection does not preclude the possibility of a mild strain being present in addition to the virulent one (see above, under 'Mild-strain protection as a control measure'). Nevertheless Amelonado indicator plants used in 'back-tests' have always, so far, shown obvious symptoms or none at all. In the experiment to compare transmission rates from seedlings with varying symptoms, some indicator plants showed delay in manifesting infection, which is characteristic of milder strains; but in this instance it was probably due to the use of single mealybugs, other experiments having suggested an inverse relationship between vector number and latent period of the virus.

An experiment with Kpeve

The first replicate of a trial to compare resistance and tolerance to Kpeve (*loc. cit.*) in cuttings from the F₁ T₁₇ trees already tested against New Juaben is almost complete, only 'back-test' results for T₁₇/357 and 1071 being outstanding. Identical methods are being employed, except that Amelonado cuttings are included for comparison. The fact that a few of these seem to have escaped infection suggests that Kpeve is less readily transmitted by *Pseudococcus njalensis* than is New Juaben, while the Iquitos material as a whole seems more resistant to the former isolate than to the latter, and more so than Amelonado (44 per cent. infection diagnosed by symptoms or 'back-tests' for all Iquitos stands except the two mentioned above, as against 76 per cent.). These suggestions pre-suppose that detection of Kpeve in symptomless plants by 'back-testing' is not markedly more difficult than detecting New Juaben under similar circumstances. A system of scoring for tolerance to Kpeve is being employed, which resembles that used for New Juaben. Cuttings showing bold mottling and curling of hardened leaves, with obvious leaf abscission and stunting, are given 0 marks. Persistent leaf symptoms earn 1 or 2 marks, according to intensity; transient patterns confined to flush leaves 3; and complete absence of leaf symptoms (with diagnosis by 'back-testing') 4; except that stunting or obvious leaf abscission is taken to justify a lower mark than would have been awarded on leaf symptoms alone. The Iquitos material, with a mean score of 2.54 (range between stands 2.0-3.2), was much more tolerant than Amelonado, which averaged only 0.31 per cutting. It is too early to say how far the resistance and tolerance of individual Iquitos trees to Kpeve and New Juaben are parallel; results from subsequent replicates of the experiment are awaited with interest.

MECHANICAL TRANSMISSION (E. Margaret Holden)

Table 4 summarises the experiments which have been made in continuing attempts to transmit cacao viruses mechanically. The New Juaben virus was used in most experiments but Kpeve and an isolate from *Adansonia digitata* L. have also been used. Extracts of infected plants were prepared by grinding leaves with a neutral buffer solution containing a reducing agent and in two experiments gelatin was included in the extracting fluid. No transmissions have been recorded.

TABLE 4
Attempted mechanical transmission

<i>Virus strain</i>	<i>Source of inoculum</i>	<i>Seedlings inoculated</i>
New Juaben	Cacao*	<i>Zinnia elegans</i>
New Juaben	Cacao*	<i>Ipomoea</i> (Scarlett O'Hara Morning Glory)
New Juaben	Cacao	<i>Gomphrena globosa</i>
Kpeve	Cacao	<i>G. globosa</i>
New Juaben	Cacao	<i>Corchorus olitorius</i>
New Juaben	<i>C. olitorius</i>	<i>C. olitorius</i>
Kpeve	Cacao	<i>C. olitorius</i>
New Juaben	Cacao	<i>Adansonia digitata</i> (2-leaf stage)
<i>A. digitata</i> isolate	Cacao	<i>A. digitata</i>
<i>A. digitata</i> isolate	<i>A. digitata</i>	<i>A. digitata</i>

* Gelatin included in the extracting fluid.

CHEMOTHERAPY (E. Margaret Holden)

In some other crops thiouracil and 8-azaguanine have delayed or inhibited the development of various virus infections, and these chemicals have therefore been tested for their effects on swollen-shoot disease of cacao.

Thiouracil was used as a 50 mg./l. aqueous solution. When 250 ml. of this solution was applied daily to a box containing thirty seedlings no phytotoxic effects were observed, but higher concentrations caused stunting and distortion. Azaguanine was also used at a concentration of 50 mg./l. and was dissolved in 0.01 per cent. sodium bicarbonate solution, the higher concentrations of sodium bicarbonate which are usually used being toxic to cacao seedlings. Treatments of beans with thiouracil or azaguanine before bombardment with mealybugs from a virus source did not prevent normal feeding of the insects and had no effect on subsequent development of virus symptoms. Soaking beans for a short period in a 500 mg./l. solution of thiouracil retarded germination slightly.

Neither thiouracil nor azaguanine delayed the onset of symptoms when applied to germinating beans infected with either New Juaben

or Kpeve isolates of the virus. Both compounds increased the severity of the symptoms causing greater stunting of the plants, greater distortion of the leaves and more defoliation than in untreated infected seedlings, although the concentrations used had no visible effects on healthy plants.

In one experiment there was a marked delay in the appearance of symptoms when month-old seedlings were watered with thiouracil solution after being infected by mealybugs with the New Juaben virus. Further experiments with infections made to seedlings which were treated with thiouracil both before and after bombardment failed, however, to confirm this result. The number of mealybugs used for transmission of the virus varied in different experiments and the possibility that this is a relevant factor in the discrepant results obtained is being investigated.

Azaguanine treatment of seedlings before and after infection has in none of the experiments caused a delay in symptom appearance.

BLACK-POD DISEASE

(A. L. Wharton)

SPRAYING AND HARVESTING TRIALS

The results of this year's work on fungicidal spraying have largely confirmed those of the previous year (*Ann. Rep. WACRI*, 1955-56, p. 42), and Trial I has now been terminated. Because of the effectiveness of the 'frequent' rate of application last year the plots receiving this treatment were split so that a second 'frequent' spray treatment could be included. This involved a reduction in the number of spray applications to eight, made at fortnightly intervals during the mid-crop season when the disease is most prevalent.

Yields in terms of pods per tree are given in Table 5 and a footnote to this table explains the three 'frequency of application' treatments in detail.

The effects of regular and frequent harvesting, in the absence of fungicide sprays, are now well established. Increases of 50 per cent. in the weight of good beans recovered per pod were again achieved by weekly harvesting compared to monthly.

All the fungicide sprays reduced black-pod disease to extremely low levels, the most effective treatment (1.7 per cent. infection) again being Carbide-Bordeaux mixture applied at the F_1 frequency and combined with weekly harvesting. The progressive decrease in levels of disease on the unsprayed control plots may be attributed to reduced sources of infection following three years spraying on the intermingled treated plots. Because of this, little more information could in fact have been obtained by continuing the trial, and differences in effectiveness

between the various treatments may be more marked than this year's results suggest. From the figures presented the expense of the F_1 frequency of spraying, involving twenty-four applications per annum, could hardly be justified compared with monthly spraying. However, it is not known to what extent the 'frequent' spraying treatments helped in reducing spread of disease into the monthly sprayed plots, as has apparently happened with the controls.

TABLE 5
Trial I: yields for 1956-57

<i>Fungicide</i>	<i>Frequency of application</i>	<i>Frequency of harvesting</i>	<i>Total pods per tree</i>	<i>Un-damaged %</i>	<i>Black pods %</i>	<i>Rodent damaged %</i>	<i>Otherwise damaged %</i>
Unsprayed (control)	—	Weekly	79.7	71.3	10.0	12.4	6.3
		Monthly	58.9	59.1	17.8	17.3	5.8
Carbide-Bordeaux mixture	F_1	Weekly	53.3	72.2	1.7	18.6	7.5
		Monthly	41.0	78.6	4.1	14.6	2.7
	F_2	Weekly	74.7	82.6	3.3	10.2	3.9
		Monthly	48.9	69.1	4.9	22.7	3.3
	F_3	Weekly	84.6	77.7	3.1	14.2	5.0
		Monthly	59.3	74.8	5.7	16.0	3.5
Ordinary Bordeaux mixture	F_1	Weekly	75.0	83.6	4.1	8.4	3.9
		Monthly	74.8	61.4	6.7	27.4	4.5
	F_2	Weekly	52.3	72.9	5.7	15.3	6.1
		Monthly	68.4	68.7	8.8	18.1	4.4
	F_3	Weekly	67.6	80.4	6.4	8.9	4.3
		Monthly	49.8	64.7	7.2	19.7	8.4
Perenox	F_1	Weekly	85.5	80.5	2.1	13.1	4.3
		Monthly	60.0	68.7	5.0	22.3	4.0
	F_2	Weekly	61.6	77.8	5.2	12.5	4.5
		Monthly	43.7	73.4	7.1	15.6	3.9
	F_3	Weekly	59.4	74.4	5.4	15.3	4.9
		Monthly	57.0	73.8	7.2	15.8	3.2

F_1 —24 applications per annum—weekly, fortnightly or monthly depending on the seasonal incidence of black-pod disease.

F_2 —8 fortnightly applications from May to August.

F_3 —12 monthly applications.

On this cacao four years ago losses from black-pod disease were as high as 30-35 per cent. of the crop, and the trial has shown the efficiency of the fungicides used in reducing these losses to insignificant levels. The most promising type of chemical treatment has been that in which the sprays are concentrated at the time of year when the disease builds up, but even during this period of about two months, several fungicide applications are necessary. Because conditions are ideal for the spread of infection over this relatively long period there does not appear to be any immediate point in trying to work out an accurate system of forecasting outbreaks of black-pod disease in Ghana. An assessment of the seasonal incidence of the disease for any particular area provides a sufficient basis for a spraying programme.

In Trial I, for example, the F_1 frequency was based on two years' records for this cacao, and when it was introduced in the third year showed an immediate improvement on the F_3 frequency. The beneficial effects of weekly spraying during May and June were apparent even in the last quarter of the year, when the fungicide was applied monthly in both treatments. From the single season's results with the F_2 treatment it would appear that the number of applications during the mid-crop season can be considerably reduced after one year.

Further improvements in disease control measures are dependent on a more detailed study of such aspects as extraneous sources of infection, of which infected soil may be the most important, better methods of spraying pods in the canopy, and increased persistence of the fungicides used.

Two more exploratory fungicide trials were conducted during the year, but in each case the results have been of no value because of the lack of disease in the control plots. Trial III was to compare the effectiveness of two new copper fungicides—an oil emulsion (Oleocuire) and a new formulation of copper oxychloride (Wettable Blidust)—with Perenox as a standard, and unsprayed plots as control.

Trial IV was a purely experimental examination of a fresh approach to the problem of protecting individual cacao pods from black-pod disease. The object was to cover pods with an inert plastic coating which would serve essentially as a mechanical barrier to the penetration of fungus spores. For this purpose a 20 per cent. aqueous solution of a vinyl-latex resin was applied, pods of all ages being individually sprayed once using a 'flit-gun'. The chemical did not damage the fruits sprayed or increase the number of cherelles which wilted. Two months after spraying the film was still intact on growing pods, confirming the stretching properties claimed by the manufacturers. Unfortunately, of the 201 unsprayed pods only eleven developed black-pod disease and although none of the 215 sprayed pods became infected a valid comparison is not possible.

CUSHION INFECTION

On the second 'pod-painting' experiment (see *Ann. Rep. WACRI*, 1955-56, p. 47) the occurrence of a relatively small proportion of 'black pods' in the ripe pods harvested during the year has rendered the season's results of little value.

Estimates of cushion infection from the first 'pod-painting' experiment (*loc. cit.*) were obtained by assessing the expected numbers of 'black pods' on the treatment trees if pods had not been brush-painted with a fungicidal paste. This assessment was based on two years' pre-treatment records for the treated trees and those in the nearby unsprayed control plots of Trial I. An additional year's post-

treatment records have now been taken on the trees originally treated and these have confirmed the accuracy of the assessment, and hence the estimates of pod infection arising from the cushions.

EFFECT OF AGE AND SIZE OF POD ON SUSCEPTIBILITY

Investigations have been started into the frequency distribution of black-pod infections (proximal, lateral and distal) on pods of different ages and sizes over a complete season, taking into account the effect of climatic factors and pod populations. Related to this work are studies, which are being carried out in conjunction with the plant physiologist, on flowering and fruiting frequency, the life expectancy of individual cushions and the extent of adventitious cushion development on mature and young cacao trees.

Within an area of old Amelonado cacao where the disease is known to be severe, 200 trees are examined every two days and on each occasion new fruits which have set are labelled and numbered. Any fruits suffering from wilt, black-pod disease or damage due to other causes are removed and classified, the length and diameter of the fruit on removal also being noted. Pods which reach maturity without damage are measured and the date of ripening recorded; they are then left on the trees, subject to natural disease infection, for a further arbitrary period of six weeks before being harvested. If during this period they become diseased or suffer other injury they are harvested and classified.

Records have been taken for one year but the classification of all the 3,869 pods into their different age and size groups for each week of the year is not yet complete.

Of the 401 'black pods' recorded during the year, 179, 99 and 123 were respectively fruits less than 13 cm. in length (cherelles), green pods above 13 cm. in length, and ripe pods. Distal or lateral infections of young cherelles, which are much more numerous than was previously realised, accounted for most of the early season 'black pods'. In the second quarter of the year, for example, sixty-two of the seventy-five 'black pods' harvested were cherelles and of these fifty-one (82 per cent.) had distal or lateral infections.

Proximal infections arise later, on the bigger cherelles and immature pods. It is not known what proportion of these arise from diseased cushions but infection from these tissues has undoubtedly finished before the main crop months of October to December. During the latter period, lateral infections predominate on ripe pods. It may be noted that the 123 diseased ripe pods recorded represent a potential crop loss of 10 per cent. on this cacao area. Of these 123 diseased pods only eight and twenty-five respectively were recorded in the first week and fortnight after ripening. Thus, as suggested by

the results for Spraying Trial I (see *Ann. Rep. WACRI*, 1955-56, p. 44), the effect of regular weekly harvesting, apart from reducing sources of inoculum, is to lower the chances of ripe pods becoming infected rather than to increase yield by improving bean recovery from diseased pods. The great majority of diseased pods are, in fact, immature.

STRAINS OF *PHYTOPHTHORA PALMIVORA* OCCURRING IN NIGERIA AND GHANA

In view of the different results which have been obtained in Nigeria and Ghana in experiments on the fungicidal control of black-pod disease, a comparative study of isolates of *P. palmivora* from the two countries has been initiated. This work is of particular importance in relation to the selection of cacao resistant to *P. palmivora*.

It was not considered advisable to exchange cultures between the two territories and therefore the Commonwealth Mycological Institute* at Kew in England was asked to co-operate in preliminary investigations into the growth and pathogenicity of the isolates. This involved sending both cultures and pods from the two countries to Kew.

The first series of tests there suggested that isolates sent from Nigeria differed markedly from those sent from Ghana. In a second series of tests difficulty was experienced with the technique of inoculating cacao pods, which cast doubt on the validity of the initial results. It was decided therefore that more extensive investigations should be carried out in West Africa, and a joint programme of work has been drawn up with the Pathologist of the Federal Department of Agricultural Research in Nigeria to study Nigerian and Ghanaian isolates in the respective territories. There are obvious drawbacks to these arrangements (ideally isolates from the two countries should be included in the same tests) but it should be possible to pick out markedly different isolates, which might then be compared together at Kew.

Of the collections so far examined the outstanding difference has been in the growth of the fungi in oatmeal agar culture, the mean rate of growth per day for Nigerian isolates being 1.8 to 2.0 mm. and for those from Ghana 17.9 to 22.7 mm. No differences have yet been recorded between isolates from the same country. Extensive collections will be made during the early rains of next year.

RESISTANCE AND TOLERANCE

Detailed pod disease records are being taken for all the clones included in the 1st Clonal Trial and for each tree on the 9th Progeny

* We are indebted to the Commonwealth Mycological Institute staff concerned for the time and attention they have given to this problem.

Trial area. All the trees are examined twice weekly to ensure that diseased cherelles do not escape detection. Any diseased pods which cannot be classified in the field are brought to the laboratory for isolation and identification of the pathogen concerned.

Both for resistance studies, and for testing the pathogenicity of different isolates, a reliable method for inoculating unwounded cacao pods with *P. palmivora* is essential. Work on this problem has been started.

MEALYBUG STUDIES

The possibility of controlling or reducing the spread of swollen-shoot disease of cacao through the control of the vectors by insecticides has been examined by previous workers but successful results have not been achieved because of difficulties presented by the complex ant-mealybug relationship. For example, colonies of the principal mealybug vector are protected from direct insecticidal attack by the cartons constructed by attendant ants. Earlier efforts to disrupt the association by manual removal of ants nests, grease-banding, and DDT or BHC sprays have also met with comparatively little success. Elsewhere dieldrin has proved very effective against ants and the present series of experiments were set up to test its formicidal value under local conditions, and to examine critically the effect of ant removal on the mealybug population, and the combined effect on the spread of swollen-shoot disease. This work is being carried out jointly with the Ghana Department of Agriculture.

EFFECT OF DIELDRIN ON ANT ACTIVITY (D. J. Taylor)

The first experiment was designed to assess the effect of dieldrin sprays on ant populations in cacao. Although no attempt was made in this preliminary work to follow the spread of swollen-shoot disease, the plots were sited around areas from which diseased trees had been removed in the course of normal swollen-shoot control operations, in order to simulate conditions which would be encountered in practice should the method prove fruitful and merit general adoption. The plots were at Bosuso, Bunso and Asiakwa.

A 30-yard-wide belt was demarcated around each outbreak and all trees, both cacao and forest, were sprayed with 1 per cent. dieldrin aqueous emulsion, with a 'Motoblo' motorised mist-sprayer, at the rate of 10 gallons per acre. Trees were individually treated, the spray being directed to the lower 8-10 ft. of the trunk. The spray gang first moved around the outbreak in a clockwise direction, and then returned in the reverse direction, thus ensuring that the whole of the lower trunk surface of every tree received a heavy dieldrin

deposit over which ants would have to pass as they moved up and down between the ground and the canopy.

Before spraying, and at weekly intervals after spraying, all trees, including forest species, were surveyed for ant activity. During the survey trees were examined from ground level, and for recording purposes ant-activity was classified into three groups:

- A. Single or few wandering ants.
- B. Definite column moving up or down the trunk. Aggregation of ants around a mealybug colony.
- C. Several or many columns moving up or down the trunk (this is more frequently observed on forest trees). The presence of nests containing all castes.

The results are presented in Table 6. The Bosuso plot received a second application of dieldrin after the eighth ant resurvey.

TABLE 6
Effect of dieldrin on ant activity

Activity group	Total number of ant infested trees (all ant species)								
	Bosuso			Bunsu			Asiakwa		
	A	B	C	A	B	C	A	B	C
Initial survey ..	32	135	21	13	34	2	100	185	46
1st weekly resurvey	4	3	4	1	0	0	5	6	1
2nd " "	5	5	2	0	1	0	20	4	0
4th " "	20	3	2	1	2	0	73	9	1
8th " "	48	10	2	10	3	1	108	21	3
16th " "	61	10	1	38	2	4	164	27	50
24th " "	97	13	15	37	6	12	178	40	89

In each plot the spray application was followed immediately by a dramatic reduction in ant numbers and activity. Organised ant activity was completely disrupted, and the vast majority of nests became moribund. After a period varying with the different plots between four and eight weeks reinfestation began, partly from nests which had not been eliminated and partly from outside the plot. However, re-establishment of organised activity has taken very much longer. A striking feature has been that neither of the two main mealybug attending groups, the *Crematogasterini* and the *Pheidolini*, have effectively re-established themselves even after twenty-eight to thirty weeks. Table 7 gives the data for these two groups and for *Oecophylla*, collected from the Asiakwa Plot.

Oecophylla longinoda, one of the dominant ants of cacao, was firmly re-established after sixteen to eighteen weeks; nests first appeared one month after spraying, and numbers increased rapidly after two months. Another leaf nesting ant, *Macromischoides aculeatus*, also became re-established after about sixteen weeks. Both these ant species are inimical to the mealybug-attending groups.

TABLE 7
Effect of dieldrin on different ant groups

Activity group	Crematogasterini			Number of ant infested trees Pheidolini			Oecophylla		
	A	B	C	A	B	C	A	B	C
Initial survey ..	16	91	21	11	15	13	54	77	3
1st weekly resurvey	3	0	0	0	0	0	0	4	0
2nd " "	11	0	0	0	0	0	5	2	0
4th " "	15	2	0	2	0	0	43	6	1
8th " "	18	2	0	2	0	0	59	24	3
16th " "	49	2	2	3	1	0	76	17	45
24th " "	55	9	2	4	1	0	60	22	81

This difference in establishment between *Oecophylla* and *Macromischoides* on the one hand, and the *Crematogasterini* and *Pheidolini* on the other is probably associated with the different nesting habits of the various species. The *Crematogasterini* ants build nests of vegetable detritus in or on the tree trunk, whereas both *Oecophylla* and *Macromischoides* build nests on leaves in the canopy. *Pheidole* spp. nest in crevices in trunks of mature trees and in the ground, often at the base of a cacao tree. As mentioned earlier, in this experiment the insecticide was applied to the lower part of the tree trunk and no attempt was made to spray the canopy, though clearly some of the insecticide would drift upwards, giving immediate kill but little or no residual effect. The increase in the number of nests of *Oecophylla* also appears to be a seasonal effect.

THE EFFECT OF FORMICIDAL SPRAYING ON MEALYBUGS (P. F. Entwistle)

To observe the effect of formicidal spraying on mealybugs, a large-scale trial has been set up, in conjunction with the Department of Agriculture, at Oyoko. Four hundred acres of cacao have been divided equally between treated and control areas, and the treated area subdivided into two equal halves, one of which will receive an additional treatment with malathion. As from November 1956, counts of mealybugs to hand height have been made every week, on a hundred trees in each half of the treated area and on a hundred trees in the control area. Six weeks after the first dieldrin application counts of *Pseudococcus njalensis* Laing had fallen to zero, and at sixteen weeks after spraying showed very little sign of increase. Counts of species of mealybugs other than *P. njalensis* have not changed so strikingly, though a definite downward trend is apparent. In view of the much closer association of *P. njalensis* with ants than is found with other species of mealybug, this is perhaps not surprising. During the period in which counts have been made mealybug populations in the control area have remained relatively high.

Eight isolated swollen-shoot outbreaks, each only a few acres in

extent, lying between Bunso and Nkawkaw, have been similarly treated. Mealybug counts to hand height are taken on a hundred trees at each site, as at Oyoko, but fortnightly instead of weekly. The first application of dieldrin was made towards the end of December 1956 and a second treatment effected seven to eight weeks later. Four of the outbreaks were selected for an additional treatment with malathion, which was applied at the end of March 1957.

Twelve weeks after the first spraying, counts of *P. njalensis* showed a 98.5 per cent. reduction on pre-treatment population levels. This is a mean value for all eight sites. There was, however, no discernible change in the populations of vector species other than *P. njalensis*.

Due to the inadequacy of counts to hand height as a guide to mealybug population levels on mature trees, it was decided to set up an experiment in which complete trees could be employed. A 40-acre block, C Block in the Square Mile, was set aside as the treatment area and 10 acres of the adjacent B Block as control. Counts are being made of mealybugs on complete felled trees in sixteen sub-plots, four of which are in the control area and the remainder in the treated area. During each fortnight five trees are sampled in every sub-plot each of which has been allocated randomly to one of sixteen half-working days. Thus a total of sixty trees in the treated area and twenty in the control area are felled each fortnight.

Pre-treatment counts were made, and the first dieldrin spray was applied in the second week of February 1957. Figures up to the third fortnightly count after spraying show a decrease in the population of *P. njalensis* to approximately 10 per cent. of the pre-treatment value. Data on population levels of other vector species are scanty as, even in the pre-treatment counts, very few were found.

All adult specimens of *P. njalensis* found during the routine counts were retained for estimates of parasitism. In all cases, as *P. njalensis* populations fell following spraying, those of their parasites rose swiftly to a peak, naturally falling away again as hosts became really scarce. Usually the increase of parasitism was from a 1 or 2 per cent. level in pre-treatment counts to an 18 or 20 per cent. level after spraying.

Undoubtedly as ant protection decreased and mealybugs became exposed, either due to tent deterioration or to their moving from the tents, natural parasites played a part in control. But by far the greatest factor seems to have been fungus infection, probably starting in unconsumed honeydew secretions. Within a short time of spraying many colonies and isolated specimens of dead mealybugs infected in this way were found.

Records of parasitism in species of mealybug other than *P. njalensis* are not available as insufficient specimens were encountered during the routine collections.

CAPSID STUDIES

INSECTICIDAL CONTROL OF CAPSIDS (D. J. Taylor)

Field trials to assess the value of five chlorinated hydrocarbon insecticides for capsid control in mature cacao have been carried out in conjunction with the Department of Agriculture. Aldrin, dieldrin, endrin, and heptachlor were compared with *gamma*-BHC, which has already been tested extensively in the field. The trials were carried out on farmers' cacao, and were timed to cover the period of peak capsid population and high incidence of damage; the experiment was started in August 1956 and was concluded in March 1957.

In each case commercially-available emulsifiable concentrate formulations of the insecticides were used, as follows:

- Gamma*-BHC – 20 per cent. E.C. (Plant Protection Limited)
- Aldrin – 30 per cent. E.C. (Shell Company Limited*)
- Dieldrin – 20 per cent. E.C. (Shell Company Limited*)
- Endrin – E.C. containing 1.6 lb. toxicant per U.S. gallon (Shell Company Limited*)
- Heptachlor – E.C. containing 2.0 lb. toxicant per U.S. gallon (Velsicol Corporation*)

* Acknowledgement is made to the Shell Company of West Africa Limited, and to the Velsicol Corporation, U.S.A., for the free supply of insecticides used in these trials.

Five of the six treatments in the experiment consisted of two low-volume applications of the insecticides, each at 2 oz. toxicant per acre, with an eight-week interval. The sixth treatment consisted of two low-volume applications of aldrin, each at 4 oz. toxicant per acre, with a four-week interval. An aqueous emulsion was prepared in each case, applied with a 'Motoblo' mist-sprayer at the rate of 5 gallons per acre.

The treatments, which were replicated three times, were randomised over eighteen plots located in the Asiakwa, Osino South and Bosuso areas of Eastern Region. Each plot, approximately five acres in area, consisted of typical farmers' cacao uniformly affected by severe capsid damage. The initial insecticidal applications were made during the last week of August and the first two weeks of September.

The number of trees damaged by capsids after treatment was used as a measure of effectiveness. Counts were made by Department of Agriculture personnel, who passed systematically through each plot looking for newly-formed capsid lesions. Trees suffering from recent damage were labelled and recorded. The first count was carried out six weeks after the first insecticidal application, the second six weeks after the second application, and counts were continued thereafter at fortnightly intervals. The results are given in Table 8.

TABLE 8.
Insecticide trials

Treatment	Plot number	Plot size (acre)	Total number of damaged trees per plot						
			6	14	16	18	20	22	24
			weeks after first application						
Endrin	54	5.4	15	15	15	18	25	40	41
2 × 2 oz. with	57	5.5	2	2	3	3	5	5	5
8 week interval	62	3.9	4	4	4	7	8	9	12
Mean per acre*			1.4	1.4	1.5	1.9	2.6	3.7	3.9
Heptachlor	53	6.1	300+						
2 × 2 oz. with	56	4.5	100+						
8 week interval	58	5.0	100+						
Mean per acre*									
Gamma - BHC	47	3.0	23	30	35	42	54	62	82
2 × 2 oz. with	59	5.5	47	51	51	53	56	60	61
8 week interval	64	3.8	18	18	19	25	28	35	45
Mean per acre*			7.2	8.0	8.5	9.8	12.2	12.8	15.3
Dieldrin	52	6.0	53	61	64	66	72	91	98
2 × 2 oz. with	55	6.1	30	55	68	92	124	160	160
8 week interval	63	4.7	29	33	34	38	43	49	80
Mean per acre*			6.6	8.9	9.9	11.7	14.2	17.8	20.1
Aldrin	48	5.0	40	54	85	93	100	110	120
2 × 2 oz. with	50	4.9	29	43	46	50	55	59	73
8 week interval	60	6.3	53	61	62	66	74	87	106
Mean per acre*			7.5	9.7	11.9	12.9	14.1	15.8	18.4
Aldrin	49	5.4	6	48	70	80	107	132	208
2 × 4 oz. with	51	3.8	15	17	21	25	29	34	42
4 week interval	61	4.8	8	18	21	23	26	26	29
Mean per acre*			2.3	5.9	8.0	9.1	11.6	13.7	20.0

* Mean number of damaged trees per acre calculated on total acreage of the three replicates.

While it is most desirable to conduct such trials as these on typical farmers' cacao, the considerable variation within treatments emphasises the problems which arise when experimenting with a tree crop grown under conditions which are far from uniform. Comparatively large plots have to be used to ensure that each contains a similar amount and range of capsid damage, including recent attack indicating the presence of capsids, and also pockets of acutely damaged and cankered trees with little or no canopy. When using large plots the number of replicates obviously has to be limited for practical reasons.

In this trial endrin-sprayed plots suffered far less damage than plots sprayed with the other four insecticides under test, showing excellent control and protection, with subsequent regeneration of damaged trees. Good control of capsids, followed by regeneration of damaged trees, was achieved with *gamma*-BHC, aldrin and dieldrin at the double 2 oz. rate of application. The amount of subsequent

fresh attack was very small, and of the same order with each of these insecticides, no statistically significant differences existing between them in this respect. Even after six months the mean number of damaged trees per acre was only fifteen to twenty, amounting to about three per cent. at normal tree densities. The double 4 oz. application of aldrin with a one-month interval appeared to give slightly better initial control of capsids than the double 2 oz. application of this insecticide with an eight-week interval, but no statistically significant difference was apparent after sixteen weeks.

Heptachlor did not give adequate control. In one plot, six weeks after the first insecticidal application there were over 300 trees with fresh damage. At the next count carried out six weeks after the second application, a further considerable amount of fresh damage was recorded. Similar results were observed in the other two replicates and this treatment was discontinued because of the obvious ineffectiveness of the insecticide.

Of the four promising insecticides aldrin is the cheapest, and endrin the most expensive. Taking into account both effectiveness and cost the trials suggest aldrin as a most promising insecticide for capsid control, though further tests are necessary before a firm recommendation can be considered.

POPULATION STUDIES (P. F. Entwistle)

Egg counts

The experiment to investigate the possibilities of capsid population estimation by egg counts (*Ann. Rep. WACRI*, 1955-56, p. 55) was discontinued in December 1956.

Significant correlations were obtained between post-eclosion populations and counts of unhatched eggs made in the previous sampling period. Rather more important is the fact that when data were transformed to weighted fortnightly running means (one fortnight being the sampling interval) a significant correlation could be obtained between eggs and capsids of the same fortnight. It was not possible, however, to go beyond this and predict population rises from egg counts. Even had this been feasible the problem of forecasting a specific degree of population change, rather than a purely relative one, would have been complex, requiring, in the area of cacao used, an accurate estimate of available oviposition sites to which the sample removed could be related. As a means of absolute population estimation egg counts are of less value than counts of post-eclosion stages for this reason.

Experiments on the vertical distribution of eggs in mature cacao have continued. The effect on egg distribution of increased tree

spacing, where more light is incident at lower canopy levels, is indicated in Table 9.

TABLE 9.
Vertical distribution of capsid eggs

Spacing	Height		Intervals			
	0-5'	5-10'	10-15'	15-20'	20-25'	
4' × 4'	0.00	2.34	9.90	12.70	18.30	
8' × 5½'	0.00	9.34	13.44	2.97	3.40	

Data are in terms of eggs per 100 ft. of damaged tissue, and refer to trees in the 20-25 ft. height range. Comparative figures for trees in the 15-20 ft. height category are not yet available.

With increased spacing the greater part of oviposition occurs at lower to mid-canopy levels, whereas the bulk of the eggs are found in the upper canopy in more closely spaced trees. It should be mentioned here that eggs were found only in tissue that had been damaged by capsid feeding and that the distribution of this type of tissue over the tree follows closely the bulk tissue distribution.

A basic relationship is apparent between the percentage of all capsid eggs in a plot of cacao that are laid in chupons, and the ratio of chupon to fan tissue within that plot. A graphical representation of the data, where the ratio of chupon to fan tissue is plotted as the independent variable and the percentage of eggs in chupons as the ordinate, shows an exponential curve asymptotic to the former factor. Two points on the graph can be determined theoretically: obviously in unjorquetted cacao seedlings all eggs present would be in chupon tissue, whilst in a plot of mature cacao in which all the chupons had jorquetted and fan tissue alone remained suitable for oviposition, all the eggs would be in fans. These two theoretical points are the first and the last, respectively, in Table 10.

Table 10.
Type of tissue and egg distribution

Chupons/fans	1:0.00	1:1.45	1:4.62	1:5.00	1:38.52	1:∞
Eggs in chupons %	100.00	66.70	50.09	40.13	19.62	0.00

Even in areas where capsid populations are high, competition for breeding seems to be negligible. If such competition existed correlation between the length of a chupon or a fan and the number of eggs laid in it would be expected. Calculated correlation coefficients, how-

ever, are not significant. This is perhaps not surprising when it is recalled that an average of two capsids per tree indicates a high population level.

Capsid culture

Attempts to develop a more efficient method of capsid culture than that in use at present were started during the period under review. Promising results have been obtained using cherelles, kept in an atmosphere of high humidity, as substrate for both oviposition and feeding. Cherelles on which eggs have been laid are removed, and first-instar nymphs are transferred to a fresh food supply, also under condition of high humidity. Instead of cherelles small pieces of unripe pods have been used with almost equal success. A major difficulty has been the maintenance of surface sterile conditions on the cherelles, without damaging the eggs, during the period of incubation. Various standard fungicides are being tried.

POLLINATION STUDIES
(Helen M. Entwistle)

Entomological observations

From data collected by the writer and other workers there is no reason to doubt that midges of the family Ceratopogonidae are the principal agents in natural pollination of cacao flowers. Their frequency of occurrence in cacao flowers is correlated with variations in natural pollination rates throughout the year. There is no indication that other agents are involved. Large numbers of buds, bearing colonies of aphids, both winged and non-winged, have been caged, but neither sets nor pollinations were obtained when the flowers opened. Cecidomyidae, which are abundant in cacao flowers, have been similarly tested with newly-opened flowers, but again with negative results. Ants have been tested by previous workers.

Estimations of the number of pollinations at different times of the day, given in Table II, indicate that the midges are most active during the first three hours of daylight.

TABLE II
Pollination at different times of the day

<i>Period of day</i>	<i>Percentage of total pollinations occurring during period</i>
Dawn-07.30	37.1
07.30-09.00	49.5
09.00-12.00	1.0
12.00-15.00	12.4
15.00-18.00	0.0

There is a second smaller peak of activity in the afternoon. During the middle of the day some of the midges rest in the cacao flowers, as shown by the data from collections of insects in flowers made at different times of the day, between June and August 1956 (Table 12).

TABLE 12
Midges found in flowers at different times of the day

Time	Total number of flowers examined	Number of pollinating midges per 1,000 flowers
06.30-07.30	5,016	1.4
10.30-11.30	5,016	5.1
13.30-14.30	4,884	3.5
17.30-18.30	4,752	0.4

The midges first appear in April-May, and gradually increase in numbers until about October, the population remaining high to the end of the year. The advent of the harmattan in January causes a sudden fall, and from February to March the population continues to decline, as the breeding sites dry out. By March, when flower numbers rise steeply with the start of the flowering season, pollination has virtually ceased. The midges breed in decaying organic matter which is constantly saturated with water—rot-holes in trees, fallen logs, etc. They probably survive the dry season in the egg stage.

Botanical observations

As shown by Posnette (*Trop. Agric., Trin.*, 19, p. 188, 1942) stylar pollination is effective in causing setting. A further series of hand pollinations indicated that, in fact, it is more efficient than pollination on the stigma (Table 13); this point is important as a large proportion of natural pollinations are stylar.

TABLE 13
Stigmatic and stylar pollinations

Type of pollination	No. flowers	No. sets	% setting
Stigmatic	19	14	73.7
Stylar	22	19	86.4

The amount of setting is determined partly by how long the cacao flower remains available for pollination, and partly by the condition of the tree. A series of hand-pollinations was carried out, in July 1956, on three clonal trees (Type D.26) to determine what proportion

of sets result when flowers are pollinated at various intervals after opening. The periods at twenty-four to twenty-eight hours after opening, in Table 14, correspond to the main peak of pollination on the second day, when both stylar and stigmatic pollinations were used. It is assumed that the flowers are open by approximately 06.30 hours.

TABLE 14
Age of flowers in relation to setting

<i>Hours after opening</i>	<i>Type of pollination</i>	<i>Number of flowers pollinated</i>	<i>Number set</i>	<i>Percentage setting</i>
2-5	stigmatic	31	24	77.4
8-9	stigmatic	35	30	85.7
11-12	stigmatic	35	35	100.0
24-25	stigmatic	23	9	39.1
24-25	stylar	22	11	50.0
27-28	stigmatic	27	3	11.1
27-28	stylar	35	5	14.3

In both cases, the stylar pollinations were more effective than the stigmatic.

ESTABLISHMENT AND MAINTENANCE TRIALS

(R. J. Benstead)

EXPERIMENTAL PLOTS

The condition of the cacao has improved considerably, with greatly increased yields. Experience has shown that Amelonado cacao produces its first appreciable crop in the ninth year, and the areas planted in 1947 have thus reached a productive age. It is difficult therefore to attribute the improvement to any one factor, but there is little doubt that capsid control and shade reduction have had a marked effect.

An effort was made to reduce overhead shade by approximately 50 per cent., but owing to the resistance of a number of the forest tree species to the arboricide used, effective shade reduction on some areas did not amount to more than 25 per cent.

The incidence of black-pod disease in the young cacao in experimental areas (7-9 years old) was extremely low, only 0.38 per cent.

of the pods harvested from the Amelonado cacao and 0.03 per cent. from the Upper-Amazon being unfermentable.

ESTABLISHMENT AND UNIFORMITY TRIALS

The 1st Establishment Trial has been re-designed as a simple Manurial and Shade Trial, but yield recording on the original treatment plots has been continued to provide pretreatment data for the new experiment. Shade has been reduced throughout the area by the removal of 50 per cent. of the *Gliricidia* shade trees, and on half of the area all the remaining shade trees are to be destroyed by poisoning. Overall yield for the 1956-57 crop season was 169.3 lb. of dry cocoa per acre, plot yields varying between 34 and 549 lb. per acre.

On the 2nd Establishment Trial no significant differences in yield between treatments have been recorded. The pruned trees have maintained a low canopy, which makes access for routine operations extremely difficult.

The 10-acre Uniformity Trial area, planted with Amelonado in 1947, has yielded 93 lb. of dry cocoa per acre. This cacao was markedly over-shaded with *Gliricidia* and 50 per cent. of these trees have been removed to induce canopy integration.

SPACING TRIALS

The cacao in the Amelonado Spacing Trial is in its ninth year from planting, and yields from all treatments have reached an economic level. Data for the 1955-56 and 1956-57 seasons are shown in Table 15.

Table 15

Yields from the Amelonado Spacing Trial for the 1955-56 and 1956-57 crops

<i>Spacing</i>	15' × 15'	12' × 12'	10' × 10'	7½' × 7½'	7½' × 6'	6' × 6'	5' × 5'	4' × 4'
Equivalent density (trees per acre)	193	302	435	774	968	1,210	1,742	2,722
Pods per tree								
1955-56	6.8	5.1	4.0	2.9	1.8	1.6	1.3	0.5
1956-57	25.12	15.78	13.21	11.57	7.47	5.57	4.78	2.43
Dry cocoa per acre								
1955-56	109.4	128.4	145.0	187.1	145.2	161.3	188.7	113.4
1956-57	440.8	433.2	522.4	815.5	657.4	612.7	757.0	601.3

The progress of the cacao in the Upper-Amazon Spacing and Pruning Trial has been disappointing, as may be seen from the figures

recorded in Table 16. This cacao too was rather heavily shaded, and a programme of shade reduction has therefore been started. There are no statistically significant differences in the yield data between treatments, though there are indications that pruning increases yield at the wider spacings.

It is regretted that data for 1955-56 were incorrectly presented in the previous report. The correct figures are included in the Table.

TABLE 16

Yields from the Upper-Amazon Spacing and Pruning Trial for the 1954-55, 1955-56 and 1956-57 crops

Spacing	8' x 8'			10' x 10'			12' x 12'		
	1954-55	1955-56	1956-57	1954-55	1955-56	1956-57	1954-55	1955-56	1956-57
<i>Unpruned plots</i>									
Pods per tree	4.92	4.14	5.69	6.56	6.22	8.74	9.09	8.54	10.42
Dry cocoa per acre (lb.)	298.7	234.6	322.4	255.4	226.0	317.6	245.1	214.9	262.2
<i>Pruned plots</i>									
Pods per tree	4.71	3.82	5.16	6.76	4.05	9.19	9.20	10.39	12.34
Dry cocoa per acre (lb.)	286.0	216.5	292.4	263.2	147.1	333.9	248.1	261.5	310.6

ARBORICIDE EXPERIMENTS

A programme of shade reduction on experimental cacao areas was started in April 1956. The shade trees were mostly about ten years of age, and in addition to *Gliricidia maculata*, planted as semi-permanent shade, thirty-six species, which had developed either as volunteer seedlings or coppice shoots following clear felling, were represented. Girth of the trees varied with species, but could be considered as typical of those found on secondary bush of this age.

A proprietary arboricide (Phortox) consisting of a mixture of the esters of 2, 4, 5-T and 2, 4-D with an oil base was used. This was diluted with kerosene at the rate of one pint to five gallons, and the solution applied to the bark between ground level and a height of eighteen inches using an ordinary two-inch paint brush.

Although the operation was intended to be a purely routine method of reducing shade, observations were made on a number of trees of each species for a period of six months, and these are summarised in Table 17.

Leguminous trees appear to be particularly susceptible, and trees with a copious flow of latex are generally more resistant to the arboricide.

TABLE 17

Effect of single application of Phortox applied to bark

Death two months after application	
<i>Amphimas pterocarpoides</i>	<i>Ficus exasperata</i>
Death four months after application	
<i>Albizzia zygia</i>	<i>Antiaris africana</i>
<i>Artocarpus incisa</i>	<i>Gliricidia maculata</i>
<i>Macaranga</i> sp. (probably <i>huraefolia</i>)	
Death five months after application	
<i>Persea gratissima</i>	<i>Trema guineensis</i>
Death six months after application	
<i>Blighia sapida</i>	<i>Carapa procera</i>
<i>Canthium glabriflorum</i>	<i>Celtis soyauxii</i>
<i>Ficus capensis</i>	<i>Ficus exasperata</i>
<i>Millettia</i> spp.	<i>Spondias monbin</i>
<i>Trichilia heudelotii</i>	
Partially dead or unlikely to recover six months after application	
<i>Mareya spicata</i>	<i>Myrianthus arboreus</i>
<i>Pseudospondias microcarpa</i>	<i>Sterculia rhinopetala</i>
<i>S. tragacantha</i>	<i>Solanum verbascifolium</i>
Disturbed metabolism and apparent recovery	
<i>Alstonia congenis</i>	<i>Bosqueia angolensis</i>
<i>Ceiba pentandra</i>	<i>Celtis adolph-frederici</i>
<i>Discoglyprena caloneura</i>	<i>Elaeis guineensis</i>
<i>Monodora myristica</i>	<i>Newbouldia laevis</i>
<i>Mangifera indica</i>	<i>Terminalia superba</i>

PLANT BREEDING AND SELECTION

(D. R. Glendinning)

NEW INTRODUCTIONS

The remainder of the *Theobroma* and *Herrania* species collected on the Anglo-Colombian Expedition has now been received from Kew, and most of it has been planted in the field. Cuttings of Lafi No. 7 from Samoa, and clone 12b from the Cameroons, both of which are believed to have a measure of resistance to black-pod disease, have also been received.

The recorded trials have shown a general increase in yield. The Trinidad Introductions, planted twelve years ago, have given their best crop to date, producing 50 per cent. more pods than in the previous year. All the Upper-Amazon selections have shown something of a recovery after their declining yield of recent years. The performance of three approved types are included in Table 18, together with data for an unapproved type T30 which, although not a high yielder in its earlier years, has given the highest yield, in terms of pods per tree, from the Introductions Area during the 1956-57 season. Of the approved types T76 has now come to the fore, and T12, recently approved by the British manufacturers, has also yielded more than the previous best selection, T60. Current data on wet cocoa per pod are not available for T60 and T76, as all the pods have been issued as seed. Average wet weights for the period 1950-53 have, therefore, been given in the Table, and these have been used in estimating the yields of dry cocoa per acre. In all cases bean-weights and dry cocoa yields have been computed on the basis of a 40 per cent. wet to dry conversion factor. Actual factors for individual selections have not been investigated.

The yields from some of the more interesting 'local hybrid' selections in the 1st and 2nd Clonal Trials are also shown in Table 18. SC4 is in a single plot on the edge of the trial area, a 'guard row' position, and hence has a great advantage over the other types in the body of the trial. This selection has a very satisfactory habit of growth as a clone, with near-upright trunk-like stems and a canopy high enough to allow easy access.

A 3rd Clonal Trial has now been planted, and is in general well established. The number of leaves, the length and breadth of the largest leaf, and the stem diameter are being recorded for each plant.

In the 8th Progeny Trial some of the local selections are not yet in bearing, but the Amazon types and the new crosses have cropped well in their fifth year in the field (see Table 18). The best plot is of WAE5, a cross between an Upper Amazon and an Amelonado, which gave a yield equivalent to 850 lb. per acre. The crosses between 'local hybrids' and Upper-Amazon types (WBE selections) are also proving very vigorous, with beans larger than those of the Upper-Amazon parents.

Some of the selections in the 9th Progeny Trial have borne well although only three years old. On one plot, which is apparently exceptionally fertile, selection WEB2 has given a yield equivalent to 360 lb. dry cocoa per acre, an outstanding performance at this age.

TABLE 18
Performances of some selections: 1956—57

	<i>Number of plots</i>	<i>Age from planting out (years)</i>	<i>Pods per tree</i>	<i>Wet wt. of beans per pod (gm.)</i>	<i>Estimated mean dry bean wt. (gm.)</i>	<i>Estimated dry cocoa per acre (lb.)</i>
<i>Introductions</i>						
Trinidad Introductions Area						
14' × 14'						
T76	2	12	60.8	107.1	1.05	1,280
T30	2	12	64.6	93.3	1.11	1,185
T12	2	12	56.1	100.5	1.14	1,090
T60	2	12	55.4	91.9	0.99	995
<i>Clones</i>						
1st Clonal Trial						
10' × 10'						
ACU85	6	10	24.6	107.5	1.32	1,015
A46	6	10	17.9	145.9	1.51	1,000
2nd Clonal Trial						
8' × 8'						
R15	6	8.5	15.8	131.5	1.50	1,240
ICS1	6	8.5	9.9	161.9	1.60	960
SC4	1	8.5	23.6	128.1	1.38	1,820
<i>Progenies obtained by self-pollination</i>						
2nd Progeny Trial						
10' 4" × 10' 4"						
TF1	9	15	20.6	123.8	1.32	900
E1	9	15	18.6	124.0	1.27	815
U6	9	15	18.5	115.4	1.24	755
8th Progeny Trial						
8' × 8'						
WB2	4	5	3.9	117.5	1.25	275
<i>New crosses</i>						
8th Progeny Trial						
8' × 8'						
WE4	4	5	9.8	96.6	1.09	570
WE4*	1	5	12.1	96.6	1.09	700
WE3	2	5	10.2	79.9	0.92	490
WAE5	1	5	11.8	119.9	1.12	850
WBE2	2	5	5.5	128.7	1.23	425
WBE3	2	5	6.8	129.4	1.24	530
9th Progeny Trial						
10' × 10'						
WLB2	5	3	2.7	103.7	1.12	1071
WEB2*	1	3	9.0	103.7	1.12	360

* The plots of WE4 and WEB2 for which data are given separately are the best plots; the other data given for these varieties refer to all plots including those given separately.

Regular recording of the 2nd and 4th Progeny Trials has been discontinued, but records will be taken at intervals on the former, and also on the 1st Progeny Trial, which has not been recorded since 1954, to detect any long-term trends.

VARIETY TRIALS IN GHANA AND NIGERIA

On the nine Series I Variety Trials planted in Ghana growth rates have varied widely, as might be expected in view of the considerable

soil and climatic differences between sites. The relationship between the rates of growth of pairs of varieties, as measured by the diameter of the stems, varies from one site to another, and it seems that different varieties have different degrees of tolerance to particular conditions. This suggests that selection of types to suit particular areas may be possible, and perhaps advisable as a long-term project.

As conditions seem rather similar at Kwadaso and Bechem the Kwadaso trial is being left under fairly heavy shade, while the other trials are all under reasonably light shade. At most sites the cacao is now coming into bearing, but the drought in February 1957 has done considerable damage in some of the trials, particularly at Goaso.

Two trials of this series were planted as seed-at-stake in Western Nigeria during the season, one at the I.N.A. farm near Ibadan, and one at Ibule near Akure. Three further trials are to be planted in Western Nigeria in 1957, using basketed seedlings, and one is to be planted in Eastern Nigeria.

Four of the Series II Trials, comparing various new crosses similar to those in the 8th and 9th Progeny Trials at Tafo, were planted in Ghana this season, at Pankese, Asikuma, Apedwa and Oyoko, and four more will shortly be planted at Buaku, Fumso, Foso, and Akaa. The trial at Akaa will replace the trial originally planned for Wamfie. Two trials of this series are also to be planted in Western Nigeria, and one in Eastern Nigeria.

NATURAL POLLINATION

Planting of seed from the 1st Albino Plot has been discontinued, as this plot is unlikely to yield much more information. The plot consists of budded trees of an Amelonado clone that is heterozygous for a recessive gene which gives rise to albino seedlings. The trees are planted in a square, six by six, so that there is a central group surrounded by a square of twelve trees, outside which is a further square of twenty trees. The whole plot is surrounded by continuous cacao. Unfortunately of the central four trees two have failed, and there are thus only two trees in this group. Pods resulting from pollinations within the plot give on average one albino seedling to three normal seedlings, while pods resulting from pollination from the surrounding non-albino cacao give no albinos. In some cases a proportion of albinos lower than would be expected from the 1 : 3 ratio is observed. This is probably due to double pollinations, or mixed pollinations, involving pollen both from within and without the plot, and they have, therefore, been regarded as two pollinations, one of each type.

An analysis of co-variance of the 'foreign' pollinations on the total pollinations for the period 1951 to 1956 did not give a significant result for the differences in the frequency of 'foreign' pollinations at

different distances from the non-albino cacao (F ratio 2.33 with 2 and 24 degrees of freedom; the calculation being based only on trees on which ten or more pollinations had been identified). The totals for the tree groups, including all trees, are given in Table 19.

TABLE 19
Albino plot pollinations

	<i>Pollinations from within the plot</i>	<i>Pollinations from outside the plot</i>
Outer ring of twenty trees	169	136
Second ring of twelve trees	198	165
Inner group of two trees	49	28

This plot has thus demonstrated that a considerable proportion of pollination takes place across two intervening trees, though there seems to be rather less pollination over this distance than over shorter distances. Work is continuing on the 2nd Albino Plot, which consists of a square of thirteen trees by thirteen. It is hoped that this larger plot may give clearer results.

The 5-acre block of self-incompatible E1 cacao at Bunso Plantation is now largely in bearing, and a study of the pods revealed the presence of about a dozen trees that were not E1. Pollen from these may have contributed significantly to the setting in the plot, and the rogues were near enough to one another to obscure the influence of any one of them on the yield of the surrounding E1. All but one of them have, therefore, been removed, and it is hoped to determine the distance over which pollen from that tree is influencing setting. The flowers and small cherelles on each tree are being counted at intervals so that the number of flowers set can be related to the total number of flowers borne.

VEGETATIVE PROPAGATION

(A. D. McKelvie and R. G. Hurd)

ROOTING UNDER POLYTHENE SHEET

The rooting of cacao cuttings under polythene sheets has been adopted as a routine method at WACRI and in the Department of Agriculture. Modifications and improvements have been made during the year, so that almost 100 per cent. success is now possible with good-rooting clones. Better results have been achieved, too, with poor-rooting clones. With clone T17, for example, only 30 per cent.

of cuttings root in concrete bins, whereas 60–70 per cent. root successfully under polythene.

It has been found that a light intensity of 8–10 per cent. of sunlight over the cuttings is too low and that better results are obtained with an intensity of 15–20 per cent. sunlight. However, recent work on the effect of fertilizers on cuttings (reported below) has slightly modified this position. To prevent over-shading leaves should be cut to about half their length. This does not increase the percentage of cuttings which root but it does promote quicker sprouting of buds. It is important to restrict the amount of water applied as the soil is easily waterlogged—1 pint of water per fifty cuttings every three days is adequate.

The effect of fertilizers on cuttings

A factorial experiment has been set up to investigate the effect of NPK and Mg on the rooting and subsequent growth of cuttings. The fertilizers were applied at the following rates, per basket containing about 5 lb. of soil:

N – 0.5 gm. urea in 50 ml. of distilled water

P – 2.5 gm. commercial grade triple superphosphate, ground to a fine powder

K – 0.3 gm. potassium sulphate

Mg – 0.6 gm. magnesium sulphate

The P, K and Mg were mixed with the soil before the cuttings were set; the N application was given at monthly intervals after the cuttings had hardened (i.e. $1\frac{1}{2}$ months from setting).

This experiment is now in its fourth month and as yet there has been no observable response to either P, K or Mg. The first application of N was obviously too concentrated as three days later many of the young shoots and leaves had wilted. Although the majority of these cuttings survived, they have not recovered entirely and remain smaller than those in the other treatments. These toxic effects may have been produced by biuret in the urea solution but this is rather unlikely since the urea was from a freshly-opened bottle and the solution was freshly prepared. The experiment will be repeated using a lower concentration of urea. Nitrogen was applied in the form of urea following preliminary results of pot experiments made by Dr Arnold in which he compared the effects of different forms of N on seedling growth.

Light intensity and growth of cuttings

The above experiment showed that the time at which the dormant bud sprouted was affected by light. Of four replicate sets of treatments,

each containing 140 cuttings, two were placed under approximately 25 per cent. sunlight and two under 10 per cent. sunlight. Sixty-five per cent. of those in the lower light intensity sprouted within a fortnight, while only 39 per cent. of the other group showed signs of growth during this time. After a month, however, the same percentage had sprouted in both cases, and after six weeks those in the higher light intensity were growing more rapidly and had overtaken those in the low light conditions. Growth was measured in terms of shoot length and the number of leaves above half an inch in length. The original pair of leaves in the low light intensity remained dark green whereas those in the higher light intensity frequently turned yellow. This was probably due to more effective photosynthesis in the 'low light' cuttings, which may account for the earlier sprouting of the dormant bud.

All the replicates were placed under 25 per cent. sunlight six weeks after setting, and by the end of fourteen weeks the cuttings which had started under 10 per cent. light had almost reached the size of those which had been in 25 per cent. light continuously. The percentage that rooted was not affected by the lighting conditions.

These results suggest that the best growth of cuttings might be obtained by starting them in 10 per cent. light and then transferring them to 25 per cent. light after two to three weeks. This remains to be demonstrated in a direct experiment.

Single versus double leaf cuttings

A simple experiment is in progress to compare the performances of single leaf and double leaf cuttings under polythene sheet. Only 62 per cent. of the single leaf cuttings have rooted as against 92 per cent. of the two leaf cuttings, and in addition the growth of the new shoot is slower in the former. Similar results have been obtained elsewhere using propagating bins (see for example Evans, *Rep. Cacao Res. Trin.*, 1945-51, p. 29).

Work has started on the study of the nutritional requirements of cacao using water culture solutions. From a comparison of nutrient solutions used by other workers in this field a suitable basic culture solution, similar to Hewitt's Long Ashton Solution (E. J. Hewitt, 'Sand and Water Culture Methods', 1952), has been developed which promotes healthy growth of cacao seedlings. The composition is as follows: 0.004M. $\text{Ca}(\text{NO}_3)_2$; 0.001M. NaH_2PO_4 ; 0.0015M. MgSO_4 ; 0.003M. KNO_3 ; 0.01 m.eq./l. Fe as EDTA complex (i.e. chelated iron); 0.2 m.eq./l. Mn; 0.002 m.eq./l. Cu; 0.002 m.eq./l. Zn; 0.003 m.mol./l. B and 0.0002 m.mol./l. Mo.

The seedlings are aerated twice daily, at 7 a.m. and at 2 p.m., for

a quarter of an hour; this seems to be adequate although for quantitative work more frequent aeration will be used. Although the temperature of the culture solution varied diurnally between approximately 25°C and 32°C no deleterious effects on the plant have been observed. Three six-month-old plants have been successfully 'transplanted' from pots into water culture, after washing the soil away from their roots with a jet of water. This method is being further investigated as it may provide a short cut to the setting up of larger plants in water culture.

ROOT STUDIES

(A. D. McKelvie)

The experiment to study the growth of seedlings on two contrasting soils (*Ann. Rep. WACRI*, 1955-56, p. 65) has continued. Samples of seedlings planted in June 1955 have been harvested every month for detailed measurement. The Koforidua-type soil is in good condition but the Akwadum-type soil is in a bad state physically as it was previously a rice garden. Growth of the Amelonado seedlings on this latter soil has been poor and most of them died during the dry season. One year after planting, the seedlings were only 33 cm. high compared with 60 cm. on the Koforidua soil, while the dry weights were 13 gm. and 60 gm. respectively. The plants on the Akwadum soil were, therefore, abandoned and replaced in July with basketed Upper-Amazon seedlings. These have survived the dry season and are growing well, but a comparison of seedling growth on the two soils is no longer possible.

On the Koforidua soil the seedlings at twenty-two months old are 140 cm. high and have a dry weight of 195 gm. Table 20 shows the relative growth rate (mg./gm./day) for each month.

TABLE 20
*Relative growth rates (mg./gm./day) of Amelonado seedlings
Koforidua soil series*

<i>April '56</i>	<i>May</i>	<i>June</i>	<i>July</i>	<i>Aug.</i>	<i>Sept.</i>	<i>Oct.</i>	<i>Nov.</i>	<i>Dec.</i>	<i>Jan.</i>	<i>Feb.</i>	<i>March</i>
16.4	1.1	9.7	13.4	6.3	6.3	12.7	3.8	13.5	8.5	5.7	4.7

No relation has been found between these figures and rainfall, temperature or soil moisture. Soil moisture data, however, suggest that the low RGK in May was related to a high moisture content; while in August-September, and also in January-March, the RGR

dropped as the soil became drier. The decrease in August-September was probably also related to the lower temperature. For only about six months of the year could growth be called unrestricted.

These growth rates are based on total dry weight, which is a steadier function than leaf area increase because of the periodic flushes. It is interesting to note that dry weight always increases before flushing begins. There has been no evidence of root flushing, as seemed likely from previous experiments. The tap root has increases in length at an average of 1.5 cm. each month and this rate of increase has been maintained even after twenty-two months.

On the heavy Akwadum soil the period of growth is even more restricted, but because of the failure of the Amelonado seedlings we will have to wait another year for detailed information as to the effect of this soil on growth.

PHYSIOLOGY OF FRUITING

(A. D. McKelvie)

FACTORS INFLUENCING YIELD

Recording of flowers, pods and flushing on selection ACU 85 in the 1st Clonal Trial has continued. The results for the years 1955-57 have been sent to East Malling Research Station for analysis of the factors which contribute to yield, and until these results are analysed no definite conclusions can be reached.

For ACU 85 the outstanding difference between 1955-56 and 1956-57 was in the time of harvest. In 1955-56 there was a single main crop peak in October, while in 1956-57 the main crop peak was in November with another peak in April-May 1957. The latter peak was due to an unusual short spell of flowering in October-November and a high setting rate. The pods from this setting developed throughout the dry season and as a result took six months instead of five to mature and contained an average of only 85 gm. of wet beans, instead of the 110 gm. which is normal for this selection. Although there was some flowering late in 1955 it took place in December when conditions were very dry and no setting occurred, whereas in 1956 the dry season was later and the late flowers did set. This may have been due to more pollination or to increased setting of the pollinated flowers.

These results for the effect of climate on the developing crop are preliminary but they are beginning to give us an understanding of why the crop varies so widely from year to year and from place to

place. It seems that there is no value in the main crop setting before the first main flush occurs, since most of the cherelles wilt. This appears to hold true whether the flush is in March or in May. Flushing and flowering appear to be connected and very often they occur simultaneously. Setting is seldom high at such times but results mainly from a few flowering peaks unconnected with flushing. Both flowering and flushing seem to be inhibited when the average maximum temperature falls below 83°F. This probably accounts for the limited flowering found at Tafo in August and September. Cherelle wilt, as stated in previous Annual Reports, is connected with flushing but can also occur in prolonged droughts or more commonly when the soil is waterlogged.

It is possible to forecast when the peak of the crop will be harvested by counting five months from the date of the main crop flowering peak. This is usually the second flowering peak of the year but can be recognised by the high setting rates associated with it. In the early months of the year the number of sets per week is independent of the flowers produced but is significantly related to the state of flushing of the trees. This relation does not hold later when flowers are scarce. Over the whole year yield is strongly correlated with the total number of flowers produced and the number of flowers set. If, however, the number of sets is corrected for the number of flowers the relation between sets and yield vanishes and a correlation coefficient of 0.12 is obtained compared with 0.92 for uncorrected sets. Any apparent association between sets and yield is accounted for by both variates being associated with flowering. A correlation between flowering and yield would be expected since the heavier flowering trees within a selection are usually the most vigorous and therefore the highest yielding. There is apparently no relation between the levels of flowering in different years and the yields obtained. In 1955 there were about 350,000 flowers on ACU 85 trees and 1,767 pods, while in 1956 the figures were 550,000 and 2,063 respectively. The absence of a correlation between setting and yield is of interest as it implies that some later factor, probably cherelle wilt, controls the number of pods harvested.

The effect on yield of removing numbers of small pods from trees

An experiment has been carried out to assess the effect on yield of reducing the number of small pods, a process analogous to that of thinning the developing crop as practised with other tree crops. For the experiment selection C22 in the 2nd Clonal Trial was used, and three treatments were applied, namely, the removal of one half of the pods formed during the preceding week, the removal of one quarter of the pods, and a third treatment acting as a control where

no pods were removed. It was difficult, however, for the assistants to be very accurate in removing the correct proportion and at the end of the experiment it was estimated that one-third and one-fifth of sets had been removed, instead of one-half and one-quarter. Table 21 shows that there was no difference in yield between treatments, and an analysis of covariance with the previous year's yield failed to show any response.

TABLE 21
Effect on yield of removing small numbers of pods

	A. 1/3 sets removed	B. 1/5 sets removed	C. Control
Pods harvested ..	173	181	163
Pods wilted ..	605	846	1,077
Sets removed ..	359	277	—
Total sets ..	1,137	1,254	1,240

Although approximately equal numbers of flowers set on all treatments, with A and B treatments fewer pods wilted because many young sets were removed. With treatment C there were more pods until August-September but heavy wilting then occurred. By the middle of September the numbers of pods had fallen to a similar figure on all treatments and trial yields were approximately equal. Thus it would appear that, regardless of previous thinning of young cherelles, as the pods for the main crop begin rapid development the trees reduce their crop to a common level, probably dictated by the nutritional reserves of the tree.

Cherelle wilt in the Trinidad Introductions

Thirty selections, each represented by four trees, have been studied to find out how wilt is correlated with yield in different selections, and to find types with a low percentage wilt. The trees have been examined weekly and counts made of flowers, of healthy and wilted pods and of flushing. The experiment is to be continued for another year and final results are not therefore available. It is clear however that between selections there is no correlation between yield and percentage wilt. Some selections are high yielding in spite of high wilting, and some are poor in spite of low wilting. The average for the trial was about 75 per cent. while wilts for the four highest yielding selections, T76, T30, T12 and T60, were 64, 78, 56 and 66 per cent. respectively—in general rather less than the average.

In this experiment a correlation was found between the percentage of flowers which set and the atmospheric humidity at 9 a.m. This is being investigated further. From the experiments described above it is clear that pollination rates must decline to a very low level before yield is affected. Results from hand pollinations carried out over a number of years to produce improved seed have shown that after stripping trees of all but a very few flowers, almost 100 per cent. of hand pollinations produce ripe pods. An experiment has been started to see how low the level of setting can drop without seriously affecting yields.

Since most of the cherelles which set before the early season flush tend to wilt, an experiment was carried out to determine the effect on yield of removing all flowers formed before this flush. Six trees of selection Y₄₄ in the 1st Clonal Trial were used, and flowers were removed until the end of April, when the flush was finished. Another six trees were used as controls, and total results for the six replicates up to the end of December, when a new major flush began, are given in Table 22.

TABLE 22
Effect on yield of flower removal

				B. Untreated control		Total
A. 'Flowers removed' treatment				Before end of April	After end of April	
Flowers formed	..	..	21,524	15,416	28,900	44,316
Pods set ..	..	..	1,906	241	2,493	2,737
Pods wilted ..	..	..	1,388	223	1,962	2,185
Pods harvested ..	..	..	212	0	220	220
Wet weight cocoa per pod (gm.)			108	0	114	114

On the control trees, of the pods which had set before the end of April, 92 per cent. wilted. Flowering remained higher in the control trees until July, probably because of the upset to flowering in the treated trees. As a result in May, when the main crop set, the untreated trees had twice as many flowers as the treated trees, but there was no difference in total yield between the treatments, even when pre-treatment yields were taken into account. Thus it would appear from this experiment that when trees are prevented from wasting their reserves on cherelles before the main flush, the yield is not affected.

The effect on yield of large numbers of hand-pollinations

Large numbers of flowers on trees in the guard rows of the 1st Clonal Trial were hand-pollinated between February and August

and records taken weekly to study the effect on yield. Results are shown in Table 23.

TABLE 23
Effect on yield of hand pollinations

				<i>Hand-pollinated trees</i>			<i>Control trees</i>
				<i>Natural sets</i>	<i>Hand-pollinated sets</i>	<i>Total</i>	
Pods harvested	..	..	..	324	169	493	536
Pods wilted	..	..	..	2,500	747	3,247	2,571
Pods set	..	..	..	2,824	916	3,740	3,107
Average wet weight per pod (gm.)				99	111	102	101

When corrected for pre-treatment yields there are no significant treatment differences in the number of pods harvested. The hand-pollinated pods contained more cocoa per pod because they were mostly on the main trunk. Although 3,740 pods set on the treated trees as against 3,107 on the controls, there was little difference in the number of ripe pods. Even on the poorer yielding trees the extra setting made no difference to yield. Large numbers of flowers were hand-pollinated in April and May, but by the end of June wilt had reduced the number of pods on the treated trees to the same level as on the controls.

The percentage of pods set from hand-pollinations varied considerably during the season, occasionally reaching 90 per cent. but dropping to 50 per cent. at times of flushing and wilting. The abscission of pollinated flowers is an auxin-regulated process and may be affected by the same conditions as affect wilting. Table 24 shows the number of hand-pollinations which set each month and the number which reached maturity.

TABLE 24
Setting of hand pollinations

<i>Month</i>				<i>No. pollinated</i>	<i>No. set</i>	<i>No. harvested</i>
February	..	..	..	239	87	6
March	..	..	..	348	185	27
April	..	..	..	306	196	64
May	..	..	..	357	245	56
June	..	..	..	232	132	13
July	..	..	..	25	14	0

FREQUENCY OF HARVESTING

Wickens (*Ann. Rep. WACRI*, 1954-55, p. 55), Wharton (*Ann. Rep. WACRI*, 1955-56, p. 43) and Thorold (*J. hort. Sci.*, **31**, p. 149, 1956) have all reported an increase in total pods when trees are harvested weekly instead of monthly. Thorold attributed this to the removal of immature black pods but Wickens's experiments were on two areas where there was very little black-pod disease. Any real differences in yield should be noticeable in the developing crop and an experiment was laid down in the 1st Clonal Trial in 1956 to see if there was any physiological basis to this increased yield. Three selections, A12, A73 and K5 were chosen, and weekly and monthly harvesting treatments superimposed.

The experiment ran from June 1956 to April 1957. Records were taken each week of flowers, number of healthy pods past wilting, number of wilted pods, number of pods still able to wilt and number of pods harvested. Every week on the monthly harvested plots a bead was attached to each ripe pod, so that, at the monthly harvest, the number of pods collected could be compared with the number of beads. This was a check on theft, which could be an important factor in such experiments. In fact it was found that the level of agreement was nearly 100 per cent. each month. Table 25 gives the number of good and bad pods harvested for each month from June 1956 to April 1957.

TABLE 25
Weekly and monthly harvesting

Date	Weekly harvest			Monthly harvest		
	Good pods	Bad pods	Total	Good pods	Bad pods	Total
25/6-16/7/56	62	17	79	51	11	62
23/7-13/8	47	12	59	19	2	21
20/8-10/9	86	13	99	90	25	115
17/9-8/10	342	31	373	406	47	453
15/10-5/11	758	75	833	702	105	807
12/11-3/12	906	63	969	959	108	1,067
10/12-31/12	434	12	446	307	29	336
7/1-28/1/57	73	0	73	51	7	58
4/2-25/2	10	1	11	4	10	14
11/3-1/4	170	10	180	89	20	109
9/4-19/4	453	23	476	458	58	516
Total	3,341	257	3,398	3,136	422	3,558

There is an obvious increase in the number of black pods with monthly harvesting but no decrease in total pods. Nor was there any significant difference during the experiment in flowering or wilting. No attempt is made to explain the discrepancy between this and earlier experiments.

FLOWER COUNTING

In the past, weekly flower counts have been thought to provide a good estimate of the total number of flowers formed. It became clear in the course of the experiments on cherelle wilt that unpollinated flowers sometimes fall after one day but at other times they remain on the tree for two or three days and there appeared to be a seasonal rhythm to this variation. An experiment is in progress to determine how many of the flowers present on any particular day are new and how many remain from the previous day. In this way it may be possible to obtain a factor to convert weekly counts into a more accurate estimate of total flowers.

Flower buds about to open are marked and the number of days they remain on the tree is noted. Correction factors derived from these results vary from about 2.5 to 5.5 with a mean of 4. A low factor means that flowers remain on the tree for a long time and a high factor the reverse. No correlation has been found between the correction factor and external conditions except that a high factor occurs after very heavy storms. The correction has been applied to 1957 flower counts and has helped to smooth out certain irregularities in the flowering curve but has not altered the trend or the time of peaks.

SOIL FERTILITY, SHADE, AND MANURIAL REQUIREMENTS

ABSORPTION AND TRANSLOCATION OF RADIOACTIVE PHOSPHORUS
(R. G. Hurd and A. D. McKelvie)

An experiment is in progress using radioactive phosphorus (P^{32}) to investigate the absorption of phosphate from the soil by 4-year-old unshaded Upper-Amazon cacao trees. One of the aims of the experiment is to determine the uptake of P^{32} , and hence presumably of phosphatic fertilizer, at different times of the year. Preliminary experiments have indicated that uptake varies considerably during the year, and it may be possible to forecast the optimum times for the application of phosphates to the soil.

At monthly intervals four trees in the plot are selected at random, and for each tree, a total of 180 ml. of 0.005 per cent. H_3PO_4 , with an activity of about 2 mc., is placed in nine 3-in.-deep holes arranged in a circle one foot from the base of the trunk. Ten days later the trees are cut down and all the parts above ground are systematically assayed for radioactivity. Since the method of assay is obviously so important to the validity of the results, the procedure employed is described in some detail.

To keep the analytical work within reasonable limits a sampling technique has been devised so that each tree can be assayed in one day. Depending on the size of the tree, approximately one branch in three is analysed, the activity of adjacent branches being estimated from this one. As most of the activity is found in the leaves it was considered that an estimate based on some parameter of the leaves was most likely to be reliable, and it has been found preferable to calculate activity on the basis of leaf number rather than leaf mass.

The actual analysis involves both leaf sampling and stem sampling. Preliminary work indicated a relatively uniform distribution of activity within a flush of leaves and leaves are therefore removed in flushes. Radioactivity is measured, using a Geiger counter, on a 1 in. diameter disk cut from the middle of the central leaf and the total activity, expressed as counts per minute (c.p.m.), is calculated by proportion on a weight basis. The stems, branches and trunk are first cut into 6-in. sections, and from the centre of each section a half-in. long portion is removed for counting. When the samples thus obtained are too wide to be counted directly a number of smaller disks are cut out at random using a cork borer. The total activity per 6-in. section is estimated by proportion on a weight basis, as for the leaves. The thickness of the stem and trunk sections is also measured so as to be able to estimate the correction necessary for self-absorption. A detailed determination of the self-absorption curve will be made later, but meanwhile an approximate correction factor has been derived by comparing the activity in a typical disk of wood with the activity of a thin layer of sawdust obtained from it. This approximate correction factor has been applied in the preliminary calculations of P^{32} uptake.

The final figures obtained for uptake are expressed in terms of c.p.m. per tree (above ground). The amount applied can also be expressed in these terms and by allowing for radioactive decay over the ten day period the percentage uptake by the aerial parts of the tree can be calculated.

The experiment was started in December, 1956, and the results to date are shown in Table 26. For technical reasons only three trees could be analysed in the first month. Within any one month there is considerable variation in percentage uptake between the four trees, probably due mainly to variation in the sizes of the trees although differences in soil and other factors will also have contributed. Attempts have been made to allow for this difference in size by relating the data to a 'standard tree', using parameters based on the number of leaves, height, trunk diameter and the area of cross-section of the

trunk at ground level, but the results have not been entirely satisfactory.

TABLE 26
Uptake of P³²

Month	Percentage uptake	
	Per tree	Mean
December 1956 ..	1.63	2.18
	2.56	
	2.34	
January 1957 ..	0.06	2.21
	1.53	
	1.54	
February	5.71	1.77
	0.36	
	0.77	
March	1.44	1.03
	4.52	
	0.05	
	1.41	
	1.60	
	1.04	

As yet only the percentage uptake by the tree has been estimated but further analysis of the data should give an indication of the utilisation of phosphorus, and its translocation between leaves, pods and trunk. From a preliminary examination of the available results it appears that when a tree is flushing the absorbed phosphorus accumulates in the young flush leaves, but absorption ceases when the leaves begin to lose their pink colour and turn green. No P³² has been detected in either pods approaching maturity, or small cherelles which were beginning to wilt when the phosphorus was applied to the soil. A more detailed study of P³² distribution in relation to cherelle wilt and flushing will be carried out as more cherelles appear on the trees.

All the trees used in this experiment are necessarily destroyed during the analysis, and an attempt was therefore made to study P³² uptake by means of needle counters inserted in the trunks of the cacao trees. This method gave some useful information on uptake, but the technical difficulties involved in using scaling equipment in the field rendered it unpractical.

In agreement with the findings of Cornwell (*Trop. Agric., Trin.*, **34**, 117, 1957) it was noticed that soil application gave much more uniform uptake than trunk implantation. Uptake from the soil has been higher than that recorded in Cornwell's experiments with shaded Amelonado cacao but in the present work vigorous unshaded Upper-Amazon cacao trees have been used.

EFFECT OF MAJOR NUTRIENTS ON CACAO (P. W. Arnold and R. K. Cunningham)

Trials on young Amelonado and Upper-Amazon cacao

The factorial NPK trials on young Amelonado and Upper-Amazon cacao have, with only one exception, been discontinued. Application of fertilizers in a small area around each picquet during the early stages had caused serious damage to the trees, which would invalidate any information on responses subsequently obtained.

At Bunso there is no evidence of fertilizer damage, and the experiment is being continued for at least another harvest year. Instead of localised placement, fertilizers are now applied broadcast over the whole area of each plot. The just significant response ($P=0.05$) to phosphorus shown at Bunso in the 1955-56 harvest year (*Ann. Rep. WACRI*, 1955-56, p. 62) did not repeat itself in the 1956-57 season.

A 2⁴ NPK Mg factorial experiment, replicated four times with the highest order interaction confounded, is being laid down at the Department of Agriculture Plot 1080, near Apedwa. This consists of Upper-Amazon cacao which is just coming into bearing.

Trials on mature Amelonado

The Department of Agriculture has completed yield recording for the 1956-57 harvest at the farms selected for future manurial trials. Spot plans of all the sites have been prepared by the Department, and the farms at Ant oakrom, Brofoyedru, Obuasi, Domiabra, Mampong and Juaso are to receive fertilizer applications in April-May 1957. An 'N-P' and 'K-Magnesian limestone' 2² factorial design, replicated eight times, has been adopted for all the sites. The fertilizers are to be broadcast over the plots (1,600 sq. ft.) at the following rates:

N - 100 lb. N/acre/annum (As urea—46 per cent. N)

P - 75 lb. P₂O₅ acre annum (As triplesuperphosphate—40 per cent. P₂O₅)

K - 50 lb. K₂O acre annum (As potassium sulphate—48 per cent. K₂O)

Mg (Ca) - Magnesian limestone at the rate of 5 cwt./acre/annum.

All the fertilizer applications will be made in April-May, except in the case of the nitrogen dressing which will be split so that the plots receive 50 lb. N per acre in April-May and 50 lb. N per acre in September.

Effect of major nutrients from various sources

The 'types-of-phosphate' and 'types-of-nitrogen' experiments at Kabu Hill and Nankese have been discontinued because of the difficulty of getting reliable yield records at these sites. In addition initial

fertilizer placement damage affected the 'types-of-nitrogen' experiment.

COCOA PREPARATION AND QUALITY

FERMENTATION (T. A. Rohan)

The results of the investigation into small scale fermentation of West African Amelonado cocoa (*Ann. Rep. WACRI*, 1955-56, p. 78) have been submitted for publication. An outline of this work has already been published by the British Food Manufacturing Industries Research Association (Technical Circular No. 101). The conclusions arrived at are summarised below:

1. Quantities as small as 20 lb. wet beans can be successfully fermented during the main crop season, from September until January. It has, however, been found in more recent work that the fermentation temperature in small heaps is affected by the atmospheric temperature. During the harmattan season, when night temperatures are low, the death of the beans in small heaps of about 20 lb. wet cocoa may be delayed with possible adverse effect on the quality of the resulting product.

2. Fermentation of cocoa in heaps does not take place uniformly throughout the mass. Easier access of air at the surface results in a more rapid temperature rise and earlier death of the beans than at the centre. The effect of turning should be to compensate for this, but it is not yet known if complete uniformity can be obtained even with mixing.

3. Reduction of batch size is accompanied by proportionately greater air penetration and a corresponding increase in uniformity due to a larger proportion of beans dying at about the same time. It was found that with very small batches the fermentation time could be reduced and that mixing had no noticeable effect on the quality of the product.

4. The presence of purple beans in fermented and dried West African Amelonado cocoa is not necessarily deleterious. It is probably preferable to have a product showing a degree of purple rather than completely brown, since to achieve the latter effect prolonged fermentation is required with the danger of loss of cocoa flavour. In beans which have been fermented for at least four days the anthocyanin concentration, after drying, was reduced to less than 5 per cent. of that initially present.

5. The duration of fermentation is related to batch size and where small quantities, up to approximately 250 lb. wet beans, are fermented the recommended six days is unnecessarily long. With large

heaps it is possible that longer fermentation times are required to increase the uniformity of the product.

6. Quantitative chromatographic analysis has shown that West African Amelonado contains two principal anthocyanins, four catechins and three leucocyanidins. These compounds would appear to be identical with those found in Trinidad ICS₁ material.

The apparent lack of uniformity between the top and centre of fermenting heaps of Amelonado cocoa was investigated in detail during the 1956-57 main crop season. Temperature measurements were made at the top, centre and bottom of fermenting heaps and samples were withdrawn from the top layer and from the centre at daily intervals. The polyphenols were estimated quantitatively, the pulp and cotyledon pH was measured and germination tests were carried out. Beans were examined microscopically to observe when the polyphenol storage cells liberated their contents and samples were sun-dried each day. The polyphenols were again estimated in the dried samples and the internal appearance of the beans recorded. Each sample was made into chocolate by the standard C.S.A.C. method and assessed for flavour.

This work is not yet complete but it is already clear that in large heaps there is a considerable delay in the death of the beans at the centre of the mass resulting in a marked lack of uniformity in the initial stages of fermentation. It is not yet known if uniformity is achieved in the course of time or if mixing improves the position. With reduction in batch size the death of the beans occurs more uniformly throughout the mass. Beans taken from the top layer of a fermenting heap are usually dead within twenty-four hours, and within twelve hours of their death they can be removed and dried to give an acceptable cocoa. Provided the temperature of the top layer has risen sharply to approximately 46° C. in the initial twenty-four hour period the dried product is not unduly bitter or astringent. With large heaps of the order of 2,000 to 4,000 lb. wet cocoa the death of the centre beans is delayed, necessitating longer fermentation to obtain favourable quality. There would appear to be an optimum quantity of wet cocoa, possibly related to the depth of the mass, which may be fermented with maximum efficiency.

It is too early to comment on the chemical changes which have been studied but it is hoped that more light will be thrown on the relationship between the polyphenols, in particular the anthocyanins, and quality.

EFFECT OF STORAGE ON PURPLE BEAN COUNT (T. A. Rohan)

These investigations show that there is a small change in purple bean content after six months storage which might well be attributed

to sampling and experimental errors. Quantitative estimations of the anthocyanins before storage showed that the coloured pigment was present to the extent of some 0.25 per cent. of the dry bean. It is very doubtful indeed if a reduction in purple bean content of the order of 15-20 per cent. after storage would noticeably effect quality.

Because such a very small quantity of pigment is concerned it is doubtful if even its complete removal would have any noticeable effect in itself. This is especially true in the light of recent results which show that complete removal of the colour is not necessary during fermentation.

STUDIES ON CACAO ENZYMES (E. Margaret Holden)

To obtain a better understanding of the chemical changes which take place during fermentation the properties of some of the enzymes of the bean are being studied. It has been suggested that some of the preliminary stages of germination, such as the activation of dormant enzyme systems, take place during the early phase of fermentation. In this process enzymes might be developed which are able to break down cell-wall polysaccharides. Such enzymes would cause the walls of the polyphenol-storage cells to disintegrate exposing their contents to the action of enzymes present in the other cells. Only very weak activity of the cell-wall disintegrating enzymes cellulase and polygalacturonase could however be detected in acetone-powders of fresh, germinated and partly-fermented beans; and an anatomical examination of beans fermented for various periods has so far not shown whether the cell walls are actually broken down.

Aqueous extracts of cacao tissues have little detectable enzyme activity and it has, therefore, been necessary to use acetone-powders of beans for enzyme determinations, although it is possible that this treatment may destroy part or all the activity of some of the enzymes. Samples of both fresh and sun-dried fermented, unfermented and germinated beans were prepared and pectin-esterase, amylase, catalase and β -glucosidase determinations have been made. Fermentation for twenty-four hours had little effect on these enzymes, except that amylase activity apparently increased slightly. At this stage most of the beans were already dead and the contents of the polyphenol-storage cells had started to diffuse. After fermentation for a further twenty-four hours all these enzymes had been partly inactivated and after another day no activity was detectable except for a trace of amylase. The conditions in the fermenting mass during the relatively short period between the death of the beans and subsequent inactivation of the enzymes may be of considerable importance to the end-result of fermentation.

Fresh and sun-dried beans had similar enzyme levels except that

catalase was lower in the dried samples. Although amylase is present in the bean little starch is broken down during fermentation, but this is not particularly surprising since many amylase preparations have an extremely weak action on raw starch. At present it is not known whether the β -glucosidase which splits glucose from salicin is the same enzyme as that responsible for the initial breakdown of the anthocyanins.

IBADAN SUB-STATION

VIRUS RESEARCH

(J. M. Thresh)

NIGERIAN ISOLATES OF CACAO VIRUSES

Since cacao swollen-shoot disease was first discovered in Nigeria in 1945, isolates of virus have been collected from many of the scattered outbreaks and their effects on young cacao plants studied under insectary conditions. This work was started by members of the staff of the Nigerian Department of Agriculture and was later continued by workers of the West African Cocoa Research Institute, first of all in Ghana and since 1953 also at the Institute's Sub-station in Nigeria.

Ten of the many isolates which have been collected are considered to be sufficiently distinct from each other to warrant further investigation and they are being used in a series of detailed experiments. The symptoms caused by these isolates have been followed on young plants infected by means of patch grafts and wherever possible by insects. These two methods are also being used to introduce the challenging virus in protection tests involving all possible combinations of the ten isolates.

In carrying out the detailed symptom recording it was found necessary to keep the infected plants under observation for several months, as they usually show a definite sequence of symptom development and quite different isolates of virus may closely resemble each other at an early or late stage of infection. When the plants were flushing it was found necessary to carry out the symptom observations at least twice each week, otherwise the full details of symptom development would be missed and some leaves might never be recorded at all as they are sometimes lost before maturing.

The leaf symptoms found on infected plants are of two types, the transient ones which appear on the young expanding flush leaves, and the permanent symptoms which appear as the leaves develop and persist until leaf fall. The two types of symptom appear to be

quite different manifestations of virus activity, as transient symptoms are not necessarily followed by permanent ones, and symptoms may appear on hardened leaves which were apparently normal in their immature condition.

The transient leaf symptoms are caused by an abnormal distribution of the red anthocyanin pigments in the tissues bordering the midrib and principal veins. This 'red vein banding' symptom may be mild and barely discernible, or it may be strikingly obvious, and it is most conveniently seen on cacao of the Amelonado type, which has normally little pigment in the flush leaves. As the leaves harden the red pigment of both healthy and affected leaves becomes less obvious, as it normally disappears or becomes masked by the appearance of the green chlorophyll pigments. However, the obvious red vein banding symptom may persist in some leaves, causing an intensification of the green pigment in the tissues along the affected veins. With some virus isolates the red-vein banding symptom extends into the inter-veinal areas and the leaves have a red mottled appearance, affected areas of the leaf later becoming a darker green than usual.

The permanent leaf symptoms appear as the leaves develop and mature and they are caused by an abnormal distribution of the chlorophyll pigments. They vary considerably in severity and take various forms, although the symptoms tend to follow the principal veins, particularly when the plants have been infected for some months. Permanent leaf symptoms usually occur outside the areas which were affected by the red vein banding symptom, or on the margins of these areas, and they usually undergo some modification as the leaves harden.

Of the ten isolates of cacao virus which have been kept under detailed observation, the one from Asalu and adjacent villages in Abeokuta Province has not been experimentally transmitted by mealybugs or any other insects. Furthermore, when young plants are graft-infected with this virus they first show severe necrotic symptoms and then recover. These symptoms are quite different from those caused by other cacao virus isolates and for this and other reasons the new name of 'cacao necrosis virus' is proposed for viruses of this type.

The remaining nine isolates differ considerably amongst themselves, although they are all readily transmitted by at least one species of mealybug. The virus from the Ibadan Native Administration farm gives swellings but it does not appear to give any permanent leaf symptoms, while the isolates from Alaparan and Balogun give different types of leaf symptoms and no swellings. The other isolates which have been studied all give leaf symptoms and swellings, nevertheless

they may be readily distinguished from each other by the type and severity of the symptoms they produce.

It has frequently been noted in the detailed symptom recording work and in routine transmissions, that plants which are infected by insects from an apparently uniform source of virus do not always show the same symptoms, and some of them may show symptoms which are either much milder or much more severe than those shown by the majority. Further back-tests indicate that in some instances the effect is due to certain plants tolerating infection with a normally severe form of virus, although the usual explanation seems to be that source plants are commonly infected with both mild and severe forms of virus which become segregated during the transmission work. A further possibility is that plants vary in their reaction to infection depending upon the amount of virus introduced into their tissues by the feeding mealybugs. This possibility is being further investigated in a series of experiments designed to determine the effect of infestation rate on the rapidity with which symptoms appear and on their severity. Additional evidence for the existence of virus strains has been obtained by back-testing infected trees, and it has been found that adjacent trees in outbreaks may be infected with viruses which differ markedly in the symptoms they cause and their effects on growth.

The limited number of protection tests which have been carried out indicate that at least some of the mealybug-transmitted isolates of Nigerian cacao virus are immunologically distinct, and by analogy with the more extensively studied viruses from Ghana it seems likely that further work will also reveal that differences in host range and vector specificity occur amongst the Nigerian isolates. This raises the question of their relationships. At the present time, however, it is considered that there is insufficient evidence to justify a detailed classification or subdivision of the cacao viruses occurring in Nigeria. These will still be referred to as strains of cacao swollen shoot virus, even though it is appreciated that there are various degrees of relationship and that the name is obviously unsatisfactory for some of the isolates which consistently fail to give swellings

THE EFFECT OF NIGERIAN VIRUSES ON GROWTH AND YIELD

Observations on young plants

The effect of Nigerian cacao swollen shoot virus isolates on the growth of seedlings infected at the bean stage has been investigated in further experiments carried out during the past year. This later work has extended the preliminary results set out in previous Annual Reports.

All the virus isolates which have been studied have reduced the growth of infected seedlings to an extent depending upon the locality from which the virus was originally collected, the particular insectary plants used as the immediate source of virus, and the conditions in which the seedlings were maintained after germination. Consistent differences were only obtained between isolates when the plants used as the sources of virus were selected as showing uniform symptoms typical of the locality from which the isolates were originally collected. Some of the isolates usually have a drastic effect on growth, whereas others are relatively mild, and large numbers of plants have to be used before the viruses can be shown to be having significant effects. If the plants used as the source of virus are chosen because they are showing particularly mild or severe symptoms compared with those usually produced, then the effects on growth are also atypical, and it seems that at least some of the isolates are complexes of strains, which differ markedly in the type of symptoms they produce and the severity of their effects on growth.

In one experiment a hundred plants were infected with the Offa Igbo virus isolate and compared with a similar number of healthy controls. The plants were kept under uniform conditions for three months and then half of the plants were moved to one of the insectaries with a glass roof. The other plants remained in a standard type insectary with a roof consisting of one third glass panels and two thirds asbestos sheets. It was found that after a further three months infected and healthy plants in the glass-roofed insectary had grown more rapidly than the corresponding plants in the shaded insectary. However, the effect of virus was relatively less severe in the heavy shade, as infected plants in the glass-roofed insectary had a dry weight which was 45 per cent. of that of the healthy plants under similar conditions, whereas the dry weight of infected plants in the shade was 59 per cent. of that of healthy controls. Other workers with different combinations of viruses and hosts have investigated the effects of virus infection under different growing conditions and it seems to be a general feature of virus infection that the effect on growth increases with the growth made by healthy controls.

Observations on coppiced trees

After coppicing an outbreak of swollen shoot virus at Araromi it was found that the stumps of infected trees were less likely to regenerate than the stumps of adjacent healthy trees. Furthermore, it was found that some infected stumps produced abortive shoots which died after making unsatisfactory growth. This result is similar to that obtained by Posnette (*Ann. Rep. WACRI*, 1945-46) who found that relatively few infected trees survived coppicing, and that most of them

either completely failed to regenerate, or died during the first dry season after coppicing.

Few infected trees died after coppicing the trees in and around the outbreak at I.N.A. farm. However, it was found that the growth from the infected stumps was less vigorous than that from adjacent healthy stumps of comparable size. Two years after coppicing the mean girth at the base of the best chupon growing from each of the infected stumps was 5.9 in., compared with a mean girth of 7.0 in. for the controls (difference highly significant; $P < .001$). Chupons on the largest of the infected stumps tended to grow more vigorously than those on smaller infected ones, but compared with uninfected controls the virus was having a greater effect on the larger stumps. This result is consistent with the results of the experiments already described on the effect of virus infection on the growth of young plants kept under two sets of insectary conditions.

Observations on the yield of mature trees

Yield records have been taken at the Koroboto swollen shoot observation plot since August, 1954 and an analysis of the first year's records was presented in the last Annual Report. It seemed from these preliminary results that the virus at Koroboto was having an effect on yield depending upon the length of time the trees had been infected. It was pointed out, however, that this conclusion was equivocal, and that the apparent effect could be due to the non-random distribution of capsid damage or other factors influencing yield.

Yields of both symptomless and obviously infected trees declined during the second year of the observations and the differences which could be due to the effects of virus were lower than in the previous year. As a result, only the trees which were infected before September, 1953, had a yield which was significantly different from that of the symptomless trees. Trees which showed symptoms between September, 1953 and October, 1955 had a yield comparable to that of the symptomless trees and the trees which first showed symptoms while the yield recording was in progress during the current year gave a yield significantly greater than each of the other categories, healthy or infected. It seems that the latest trees to become infected are inherently high yielding and it will be interesting to see if the yields are maintained in succeeding years.

The results from the Koroboto plot indicate that the effects of virus infection on the yield of mature trees can only be satisfactorily investigated on areas of relatively uniform cacao into which virus is introduced according to a definite experimental design. However, until cacao is made available for this type of work, records from observation plots of farmers' cacao are the only source of information,

and yield recording is now being carried out on more uniform and less severely capsid-damaged cacao near the village of Ajia, in the Ibadan area of mass infection, and near Iweka in the Ilaro area of mass infection. The plots at Koroboto and Ajia are being sprayed regularly to control black-pod disease and insect pests in an effort to reduce the variability between trees. In this way it is hoped to obtain further information on the effect of virus infection on yield, although it is clear from observations at Koroboto and elsewhere that the decline in yield is not drastic, and that virus is rarely, if ever, responsible for the death of trees in the absence of other unfavourable factors.

SYMPTOM EXPRESSION ON INFECTED TREES AND ON THE NEW GROWTH FROM COPPICED STUMPS

There is considerable variation in the type of symptom found from outbreak to outbreak and these differences are maintained when isolates of virus are collected from the field and their effects noted on seedlings in the laboratory. In addition there is also variation from tree to tree within outbreaks. This has been studied at observation plots maintained by the Department of Agriculture, whose staff keep monthly records of the symptoms shown by every infected tree. Even at outbreaks where the trees typically show leaf symptoms and swellings, some trees occur which consistently give leaf symptoms alone or swellings alone. Leaf symptoms usually precede swellings when both symptoms occur on the same tree and there is a tendency for most of the new infections to be detected at periods of heavy flush.

From time to time field officers of the Western Region Department of Agriculture report that trees which have been found with clear symptoms of virus infection have on one or more subsequent dates been found to be quite symptomless. Recent observations have again drawn attention to this problem which is an important one affecting the efficiency of all measures for the control of swollen shoot disease. An outbreak of this disease was reported at Akinlade in 1955, south of the area of mass infection, and all the known infected trees were marked after a thorough inspection carried out in May of that year. Cutting out operations were delayed and when the area was re-inspected, the number of known infections had increased from 1,324 to 3,332 in the nineteen-month interval. Some 246 of the trees which were found with symptoms in 1955 are now reported to be symptomless. This is a surprisingly high percentage, but the estimate is a reliable one as on each occasion the inspections were carried out under the close supervision of a senior officer. Furthermore, the same phenomenon has been noted at the special observation plot at Koroboto, where up to 10 per cent. of the known infected trees may be symptomless at any one of the monthly observations. It appears

from work carried out here and elsewhere, that certain trees are tolerant of infection with severe virus, while others are infected with very mild strains of virus and only show symptoms for a short time, before passing into symptomless phases of infection of variable duration. A tree which stops producing symptoms, even temporarily, is soon likely to become symptomless under Nigerian conditions, as leaves commonly persist only from one flush to the next and as a result of capsid attack branches often become damaged to such an extent that swellings become unrecognisable.

Infection with very mild strains of virus also probably explains why the new growth from infected coppiced stumps and even intact seedlings may show transient leaf symptoms and pass through symptomless phases of infection. The symptoms shown on the new growth after coppicing infected trees were studied at a swollen shoot outbreak near Araromi, south of the area of mass infection in Ibadan Province. The 114 infected trees and their contacts were coppiced in May, 1955 and regular observations were made on the subsequent regeneration. The records showed that symptom expression on the new growth was extremely irregular and until twelve months after coppicing additional infected stumps were found at each inspection. A further feature of the results was that at each inspection the number of stumps bearing chupons with symptoms was always less than the number of stumps which were alive and known to be infected. Some chupons showed transient red vein banding symptoms or inconspicuous mosaics and after being detected at one inspection they were subsequently missed when further inspections failed to coincide with periods of symptom production. Swellings have proved to be a more reliable and permanent indication of infection than leaf symptoms and particular difficulty has been experienced in detecting stumps infected with virus of the Balogun type, which only produces mild and inconspicuous leaf symptoms.

In the routine treatment of swollen shoot outbreaks by methods involving coppicing, the survey parties have experienced considerable difficulty in carrying out adequate inspection of the new growth from coppiced stumps. This is because coppiced plots tend to become overgrown if not satisfactorily maintained, and also because the symptoms on the chupons are commonly masked by mineral deficiency symptoms or the condition known as 'paint brush'. Infected stumps are usually detected during the year following coppicing, but in view of the irregular symptom expression, the occurrence of stumps infected with mild strains of virus, and difficulties in carrying out the observations, it is not surprising that some infected stumps have remained undetected until two years after the original treatment. The new growth from coppiced stumps has not usually formed a

continuous canopy by the end of the second year and there seems little chance of virus spread from infected stumps before they are detected and removed, but to minimise this risk it has been suggested that the growth from the coppiced stumps should be inspected as thoroughly and frequently as possible and certainly at intervals not exceeding three months.

THE AVAILABILITY OF CACAO SWOLLEN-SHOOT VIRUS TO MEALYBUGS FEEDING ON INFECTED TREES

Throughout 1956 experiments have been carried out to investigate the availability of cacao swollen-shoot viruses to mealybugs feeding on infected trees. After several preliminary experiments a standard procedure has been evolved which involves collecting branches or other samples from infected trees in the field, colonising them with virus-free gravid female mealybugs or crawlers and maintaining them in the laboratory for two days. At the end of that time the feeding mealybugs are carefully removed from the samples and transferred to the embryos of dissected cacao beans at a usual rate of thirty crawlers to each bean.

In one experiment five fan branch samples were collected from each of twenty selected trees at the Koroboto observation plot of the Western Region Department of Agriculture. Previous inspection of these trees had shown them to be infected with virus and the group was chosen to include ten trees which were symptomless and ten with severe and obvious leaf symptoms and swellings. The experiment was designed so that each of the five assistants involved in the work handled the mealybugs from one sample from each of the twenty trees. In this way it was possible to allow for the considerable difference in skill which previous experience had shown to exist between the different operators.

Virus was transmitted from at least one sample from each of the infected trees; but only twenty-three of the fifty samples collected from the symptomless trees were shown to contain virus, compared with successful back tests carried out on thirty-four of the fifty samples from the obviously infected ones. This indicates that virus is more extensively distributed in an available form in trees with symptoms than in trees without, and this conclusion is substantiated by the detailed transmission results. Mealybugs transferred from the samples collected from obviously infected trees infected 170 of the 381 healthy beans which were colonised, whereas mealybugs which had fed on the samples from latently infected trees infected only 76 of the 332 beans infested. Moreover, most of the transmissions from the latently infected trees were from the three which showed symptoms during the week after samples were collected from them.

The samples collected from all the infected trees were as far as possible identical, so that the transmission results indicate apparent differences in available virus content which are related to symptom expression. However, differences in the type of virus present in the two groups of trees could also account for the results and some evidence was obtained to indicate that most of the latently infected trees were in fact infected with strains of virus which were milder than those present in the obviously infected trees. One latently infected tree appeared to be tolerating infection with a severe form of virus, as all the plants infected in the back-tests from this tree gave obvious symptoms. Plants infected in back-tests from the rest of the latently infected trees showed either transient or mild leaf symptoms and never produced swellings, while their mean fresh weight four months after planting was 80 per cent. of that of healthy controls. By comparison, plants infected in the back-tests from the obviously infected trees made only 66 per cent. of the growth made by healthy controls and symptoms were usually extensive and obvious, many of the plants showing swellings at an early age.

The differences in symptom expressions were obvious in quantitative terms using a simple classification system in which seedlings which had shown only transient leaf symptoms were given a score of 1, and obvious infections with leaf symptoms and swellings a score of 5. Most of the plants were given intermediate values and the successful back tests from the latently infected trees had a mean symptom score of 1.99, compared with a mean symptom score of 3.35 for the back tests from the obviously infected trees.

The differences in symptom expression and effect on growth are strong indications that trees in an outbreak may be infected with strains of varying degrees of severity. However, these effects could be further manifestations of differences in virus content or availability. Watson & Russell (*Ann. appl. Biol.*, **44**, p. 381, 1956) have shown that the effect of sugar beet yellows virus on sugar beet seedlings is influenced by the number of viruliferous insects used to bring about infection. The explanation for this is not clear, but the effect may simply depend upon the amount of virus introduced into the inoculated plants, so that insects which have fed on tissues with a high virus content might be expected to cause the most severe infections as well as give the most successful transmission results.

In the work at Koroboto no evidence was obtained for strain variation within individual trees. All the plants infected in the back-tests from the various samples collected from any particular tree tended to show the same symptoms and using the symptom scoring system they rarely differed from each other by more than a single point. This result differs from that obtained by Posnette & Todd (*Ann. appl. Biol.*,

43, p. 433, 1955) who used grafting methods to back-test trees infected with a virus from the New Juaben area of Ghana and obtained evidence to indicate that some trees were simultaneously infected with mild and severe strains of this virus. The difference between the two experiments may be due to the different methods employed or it is possible that the New Juaben virus is inherently less stable than the one used in this work.

The transmission results which have been described were obtained under somewhat artificial conditions, but an additional experiment which was carried out on trees at I.N.A. farm suggests that natural spread from trees in the field is related to their potency as sources of virus as indicated by these laboratory tests. Ten scattered trees were 'bombarded' with mealybugs carrying the Offa Igbo virus isolate and after they had shown symptoms the trees were back-tested using the standard procedure. Each bombarded tree was surrounded by at least four controls and at the conclusion of the back-tests these trees were indexed for infection by coppicing them. As in the previous experiment the ease with which virus was transmitted from the tested trees varied with the severity and extent of the symptoms they showed, and in addition it was found that natural spread had only taken place from trees in which virus could be demonstrated most readily, using the laboratory infestation methods. All four contacts surrounding the tree which had given the most successful transmissions were infected, whereas none of the other inoculated trees had infected more than one of the four trees with which each of them was in contact.

It seems clear that, whatever the explanation, infected trees in the field vary considerably in their potency as sources of virus to mealybugs feeding on them. Furthermore, the results of the transmission tests from samples collected from trees in different phases of symptom expression, suggest that trees which are missed by the survey parties in the field because they are in an early or symptomless phase of infection, may not be really dangerous sources of virus until they produce extensive symptoms.

This possibility has been investigated in further transmission work using samples of fan-branch material collected from trees in and around a virus outbreak at the village of Odofin near Ikire. Thirty of the forty-two samples collected from the seven obviously infected trees were shown to contain virus and one-third of the infested beans became infected in these tests. By comparison, transmission tests from the six symptomless contact trees which were shown to be infected, were less satisfactory. Virus was demonstrated in only sixteen of the thirty-six samples collected from these trees and less than one-fifth of the test beans became infected. It was again found that the most successful transmissions from latently infected trees were from those

which showed symptoms soon after the test samples had been collected from them. Moreover, the success of the transmission results from the infected but symptomless contact trees was inversely associated with the length of time which elapsed before these trees eventually produced symptoms.

It is concluded, therefore, that mealybugs are able to transmit virus from at least some infected trees before they produce visible symptoms; although the likelihood of their doing this increases as symptoms are produced. This observation is consistent with observations on the spread and control of swollen-shoot virus in the field, as it has been found that cutting out only trees with symptoms is not an immediate method of arresting virus spread, even if all additional visibly infected trees are subsequently removed at monthly intervals.

It has been suggested that the availability of virus decreases as trees pass from the acute to the chronic stage of infection and it also seems likely that infected trees vary in their potency as sources of virus according to their state of flush. These and other aspects of virus availability are being investigated in further work which is continuing.

THE CONTROL OF CACAO SWOLLEN-SHOOT VIRUS IN NIGERIA

In March 1954, investigations were begun in collaboration with the staff of the Western Region Department of Agriculture to determine the incidence and distribution of latent and missed infections in and around naturally occurring outbreaks of cacao swollen-shoot virus. The routine control measures which were in operation at the time the joint work was started involved uprooting all the infected trees and the surrounding area of apparently healthy ones to a distance of at least 30 yards from the nearest infection. These measures were applied regardless of the size of the outbreak, and the main object of the WACRI investigations was to determine whether such drastic treatments were necessary and to investigate the possibility of improving or maintaining the efficiency of the control operation using less expensive and time-consuming methods.

In the course of the investigations all outbreaks of cacao swollen-shoot virus were still treated to a distance of 30 yards from the nearest infection, but only the trees found with symptoms were grubbed out and the remaining apparently healthy trees were coppiced. The number of stumps which failed to regenerate varied from site to site, but most of them produced actively growing chupons which usually showed very obvious symptoms if the tree had been infected at the time it was cut back. All the infected stumps were grubbed out as they were detected, and records were kept of their number and distribution in relation to the original infected trees which had been uprooted at the time of the initial treatment.

In August 1956 the work was reviewed for a second time and by that date 123 areas had been coppiced in treating outbreaks totalling 7,810 infected trees. On the average twenty-four apparently healthy trees had been coppiced for every obviously infected tree and only 473 of the 187,979 coppiced stumps had been found with symptoms. This figure was lower than expected, due to the complete failure of some infected stumps to regenerate and also to the fact that some of the re-inspection data were incomplete. However, it seemed clear from the results collected from the plots treated in 1954 and early 1955 that most of the coppiced trees were free of virus. It was also found that, as might be expected, the number of infected stumps tended to increase with increasing size of outbreak.

As a result of these observations it was decided to revise the treatment methods, which were made much less drastic. Discrete outbreaks of from one to ten infected trees were treated to a distance of 5 yards from the nearest infection, while outbreaks of from eleven to fifty infected trees were treated to 15 yards and the treatment of larger outbreaks remained unchanged. It is estimated that in the four months ending 31st December 1956 the introduction of the revised methods resulted in the saving of approximately 12,000 apparently healthy trees which would have been cut out using the previous methods. This represents a sum of approximately £2,500 in compensation, at the usual rate of four shillings per tree, and there were also considerable savings in the time and ease with which the marking and cutting operations were carried out. It remains to be seen whether these savings have been associated with any loss of efficiency of virus control, although this seems unlikely.

In a detailed analysis of the results it has recently been found that virtually all the infected stumps occurred within 5 yards of the original infection, where this had consisted of from one to ten trees. By comparison, about two-thirds of the infected stumps occurred within 5 yards of the original infected trees, where these numbered from eleven to fifty trees; while around the larger outbreaks only about half the infected stumps occurred within 5 yards. It seems clear, therefore, that not only do latent and missed infections occur in greater numbers around larger outbreaks, but they occur to a greater distance from the original infection. This result is consistent with observations made in Ghana and in Nigeria that small outbreaks are more readily controlled than large ones. It also gives some justification for the policy of treating outbreaks according to their size. Nevertheless, even around the largest outbreaks the probability of apparently healthy trees being infected is very low if they occur more than 15 yards from the original infection, and it seems that further changes are justified to make the control measures still less drastic. These changes

will not involve the smallest outbreaks, but those consisting of eleven to fifty infected trees will be treated to 10 yards instead of 15, while the larger outbreaks will be treated to 15 yards instead of 30. This will result in further economies at the time the initial treatments are carried out, although it seems that infection is likely to occur with some frequency amongst the standing trees on the edge of treated areas. Further treatments will be necessary but these are likely to involve only a small percentage of the perimeter trees and there seems little justification for including these in a more drastic initial treatment.

The survey parties responsible for the reinspection of the cacao around treated outbreaks not only find that some of the coppiced trees are infected, but they commonly find infected standing trees outside the perimeter of the coppiced areas. Infected trees have been found in this way around thirty-nine of the fifty-six main outbreak centres which have received treatments involving coppicing. This does not mean that the initial coppicing treatments were not sufficiently drastic, because the outlying infections are not contiguous with the originally treated centres and occur at a variable distance from them. Some outlying infections have been found on the edge of coppiced areas, whereas others have been found up to 1,000 yards away. Some of the outlying infections were found during the initial treatments, although they usually appeared at a later date, in some instances after several inspections had failed to reveal further infection.

A main outbreak and its outliers may have become infected by the movement of mealybugs from a single remote source or from separate sources. However, it seems more likely that the outlying infected trees appear as a result of spread from the nearest main centre of infection, as these may act as foci for the discontinuous or so called 'jump' type of spread in addition to the more usual continuous type of spread from tree to tree. This explanation is consistent with the available information on mealybug movement and also with the observed distribution of satellite outbreaks. The probability of these occurring decreases with increasing distance from the main centre of infection, a distribution which would be expected if the outlying trees are infected by mealybugs carried from the main centre by wind currents or possibly by ants. Satellite outbreaks occur with the greatest frequency around the larger centres of infection, although some outbreaks have many outlying infections associated with them, whereas others of a similar size have few. These differences may be due to local variation in conditions, or to differences in the size, type and behaviour of the mealybug population on the infected trees.

Satellite outbreaks are so irregular in their appearance and distribution that they cannot be anticipated. It follows that in attempting

to control outbreaks of swollen shoot disease by cutting-out operations, each discrete group of infected trees should be treated independently at the time it is found, and that a cutting-out treatment should be done with the object of dealing with the infections which are already known, and not with the hope of taking in possible satellite outbreaks situated away from the main one. The only provision which can be made at present for the occurrence of satellite infection is to carry out regular and thorough inspections of the standing trees surrounding each outbreak, particularly the larger ones and those around which infected trees have already been found.

COPPICING EXPERIMENTS

All the proposed experiments on the regeneration of cacao by coppicing have now been started and detailed recording of the early stages of regeneration has been completed. Preliminary results have been presented in the two previous Annual Reports and the work during the last year has largely consisted of routine observations and yield recording. Regular operations also include spraying against black-pod disease, as chupons on the stumps of most of the trees, coppiced in 1954, and on the stumps of some of those coppiced in 1955, are now bearing pods.

Regeneration in relation to canopy damage

In the last Annual Report it was stated that while the percentage number of stumps which survived coppicing was influenced by the severity of the damage to the trees at the time of coppicing, the rapidity with which the chupons grew on the surviving stumps appeared to be uninfluenced by the previous damage. The measurements were made during the first few months after coppicing, however, and recent observations, made after two years, show that the chupons surviving on the stumps of trees which were severely damaged make significantly less growth than the chupons from the stumps of trees which were undamaged or slightly damaged. An obvious explanation of this effect is that the root system of severely damaged trees may have been impaired by repeated capsid attack and die-back. There are other explanations, however, and it may be that the trees are suffering particularly severe damage only in areas where the soil and other environmental conditions are relatively unsatisfactory. A further possible explanation is that the grasses and other herbaceous plants which invade the ground between severely damaged trees compete with the cacao and limit the growth made after coppicing.

It has been noted in our I.N.A. experiments, and elsewhere in Western Region, that regeneration tends to be poor and deficiency symptoms particularly obvious where the previous canopy had been broken and ground vegetation already established at the time of coppicing. Various legumes are being tried as ground cover to try and overcome this competition effect and *Stylosanthes gracilis* and *Crotalaria retusa* are particularly promising.

Regeneration after coppicing considered in relation to season

At the outset of the coppicing experiments it was anticipated that during the dry season the growth of regenerating chupons would be checked, and that as a result coppicing would only be feasible at certain times of year. It became obvious from the experiments started in 1954, however, that trees coppiced during the dry season regenerated quickly and well. Furthermore, there was an indication that growth was more rapid after coppicing during the dry season than it was after coppicing during the wet.

In order to investigate these seasonal effects in more detail an experiment was carried out on four acres of regularly spaced mature cacao at I.N.A. farm, and four groups of trees were coppiced each fortnight from December 1954 to December 1955. The girth, flushing status and canopy condition of each tree were recorded at the time it was coppiced and a total of fifty trees were treated each fortnight. Weekly observations were made during the early stages of regeneration and the appearance and development of chupons was followed in detail. As the intention was to relate the rapidity with which the trees regenerated to the weather conditions prevailing at the time of coppicing, standard temperature records were taken at a Stephenson screen erected in a clearing near the site of the experiment, and rain-fall and soil temperature records were also available.

A large number of preliminary analyses of the data were carried out in order to find suitable criteria by which to measure the speed of regeneration. It was found that the time from coppicing to the stage when the most advanced chupon had reached a length of two or more inches was a convenient and valuable index of the speed of regeneration of a particular stump. The period was closely related to the number of days from coppicing to the first signs of regeneration (i.e. the appearance of developing buds on the stump) ($R = +0.913^{***}$, $N=26$) and was also related to the time from coppicing for all the potential chupons to develop ($R = +0.771^{***}$, $N=26$). Furthermore, the period was negatively correlated with the number of chupons on the stump six weeks after coppicing ($R = -0.753^{***}$, $N=26$). All subsequent analyses therefore used the mean number of days to the appearance of the first chupon

as an index of the speed of regeneration of a group of stumps.

At any particular sampling date the flushing status and canopy condition of the coppiced trees at the time they were cut back did not influence the rapidity with which chupons appeared. There were significant differences between the speed of regeneration after coppicing at different dates, however, and these were related to season. Regeneration was quicker than the average when trees were coppiced during the dry-season months of January, February, November and December, and was slower than the average when trees were coppiced in May, June, July and August. This suggested that some factor associated with the wet season was retarding regeneration and an analysis of the data showed that the weather conditions in the month after coppicing were all-important. Rainfall and temperature were considered in detail and it was found that the mean number of days to the first chupon was significantly correlated with:

1. The mean maximum screen temperature in the month after coppicing: $R = -0.52^{**}$, $N = 25$;
2. The mean soil temperature, at a depth of 1 ft. and recorded at 15.00 hours, in the month after coppicing: $R = -0.67^{***}$, $N = 25$;
3. The total rainfall in the month after coppicing: $R = +0.53^{**}$, $N = 25$;
4. The total number of wet days in the month after coppicing: $R = +0.65^{***}$, $N = 25$.

Slightly better correlations were obtained if weather conditions in the month before as well as the month after coppicing were considered, but the effect of rainfall and temperature before coppicing was small compared with their effect after. The analysis was taken a stage further by Mr G. H. Freeman (of the Statistics Department of the East Malling Research Station) who obtained a series of partial correlation coefficients and showed that both temperature and rainfall had significant and apparently independent effects on regeneration, when the variation of one was considered while eliminating the variation due to the other. This result was to be expected because temperature conditions and rainfall are not closely related in a mathematical sense. Nevertheless, the two factors obviously interact in their effect on the soil and it does not necessarily follow from the statistical evidence that temperature and rainfall have entirely independent effects on regeneration.

The observation that chupon initiation takes place more rapidly after coppicing during the dry season than it does after coppicing during the rains is perhaps unexpected, but there is no reason to think that the results obtained at I.N.A. in the season 1954-55 are

at all atypical. Similar results were obtained at I.N.A. in a less detailed experiment carried out during the season 1955-56 and Cacao Officers in various localities in the Western Region of Nigeria have confirmed that the most successful coppiced plots are those which have been treated during the dry season.

Pod yields after coppicing

Pods are not produced during the first year after coppicing and the yield during the second year has been found to vary considerably depending upon the spacing of the coppiced trees, their size and the coppicing date. The regeneration from closely spaced trees at 8 ft. $\times$ 8 ft. was in general more satisfactory than that from trees at wider spacing and most of the pods were produced on chupons growing from the stumps of trees which were greater than 16 in. in girth at the time they were cut back. From the outset, the new growth from coppiced stumps appears to show the same periodicity of bearing as mature intact trees and consequently the maximum yield during the second year after coppicing is obtained when a main crop season comes at the end of this period. Records for the various plots coppiced in 1954 illustrate this point, as few trees coppiced in August of that year produced pods during the second year after coppicing, whereas trees coppiced in October gave a mean yield of 0.8 pods per tree and trees coppiced in December a mean yield of almost 2.0.

Insect pests on coppiced cacao

Routine spraying was continued on all the coppiced plots at the I.N.A. farm throughout the year and preparations of 1 per cent. DDT or 0.1 per cent. *gamma*-BHC were applied by the spray-painting method at monthly intervals. Applied to the branch unions and jorquette this treatment gave complete protection against capsids, but did not prevent damage caused by the Noctuid moth *Earias biplaga* Wlk. This pest continued to cause damage, particularly to the tips of young and rapidly growing chupons developing from newly coppiced stumps. Routine spray-painting also failed to control the mining larvae which attack the superficial tissues of chupons and pods. This type of damage has been extensive and at certain harvesting periods the ripe pods were difficult to distinguish as they were so heavily attacked.

A black spider-mite has been found in large numbers on some of the oldest leaves on the chupons growing from the stumps of trees coppiced in 1954. The mite found in the field resembles the one which occasionally appears on old plants kept in insectaries and the damage caused is also similar. Severe attack by spider-mites is rare on cacao

in the field, and this record may be connected with the regular and intensive spraying schedule which has been practised at I.N.A. farm over the last two years using chlorinated hydrocarbon compounds.

On some of the coppiced plots maintained by the Western Region Department of Agriculture, severe damage was caused by leaf-eating larvae of an unidentified Limacodid moth. This pest completely stripped some chupons and even full-sized trees, but severe damage was restricted to certain sites and occurred only at the end of the 1955-56 dry season.

CAPSID STUDIES

(R. G. Donald)

CHEMICAL CONTROL OF CACAO CAPSIDS

This experiment (see *Ann. Rep. WACRI*, 1955-56, p. 89) has been carried out in conjunction with the Department of Agriculture, Western Region of Nigeria. After consultations with Mr T. N. Hoblyn of East Malling Research Station the design was changed in order to increase the number of replications of each treatment. As the number of staff available made it impossible to increase the total number of plots some of the insecticidal treatments had to be abandoned. It was, therefore, decided to dispense with treatments using only 1 oz. of *gamma*-BHC per acre and with treatments at twelve-weekly intervals. This decision was reached after further discussions with Mr Stapley of Plant Protection Ltd., who had had experience of capsid control work in Ghana, and with members of the Department of Agriculture, Nigeria.

Three blocks of seven 5-acre plots were selected in each of three different areas, namely Ondo Province, South Ibadan Province and Ife-Ilesha Division of Oyo Province, and the following treatments were allocated at random to the plots within each block.

- A. 2 oz. *gamma*-BHC in 5 gallons water/acre applied at four-weekly intervals from August to February using portable motor-driven mist blowers.
- B. 4 oz. *gamma*-BHC in 5 gallons water/acre at four-weekly intervals applied as in A above.
- C. 4 oz. *gamma*-BHC in 5 gallons water/acre at eight-weekly intervals applied as in A above.
- D. 4 oz. *gamma*-BHC/acre applied at four-weekly intervals from August to February using pneumatic knapsack sprayers fitted with nozzles producing a fine mist-type spray. It was at first thought that about 25 gallons per acre would be required for each application with these machines but early treatments

showed this to be too great a quantity, as the rate of delivery through the fine nozzles was very slow. Ten gallons of water per acre were, therefore, used in subsequent knapsack treatments.

- E. 4 oz. *gamma*-BHC in 5 gallons water/acre in August and September using motor-driven mist blowers, followed by spot treatments on trees showing recent damage, and on their contacts, using knapsack sprayers and *gamma*-BHC at a concentration of 4 oz. in 10 gallons water.
- F. 4 oz. *gamma*-BHC/acre applied as a dust in August and September, followed by spot treatments of damaged trees and their contacts with dust. Hand-operated dusting machines were used.
- G. No treatment.

Due to the late arrival of dusting machines treatment F was not started until September and the second over-all treatment was therefore given in October. All treatments were discontinued after February. Spraying with Perenox against black-pod disease was undertaken at four-weekly intervals from May until the end of the crop season.

In each plot a hundred trees were selected for detailed observation. As far as possible twenty trees in each of five categories were chosen, the categories being (a) full canopy, (b) $3/4$ canopy, (c) $1/2$ canopy, (d) $1/4$ canopy, and (e) canopy destroyed and the tree reduced to a trunk, with or without the main branches, and with some chupon growth. In a few plots it was impossible to find twenty trees in some of these categories and the number had to be made up with trees from an adjacent category.

The following records were taken each month for each of the marked trees:

1. Canopy category (a) to (e), as above, points being awarded as 12, 9, 6, 3 and 0 respectively.
2. Regeneration of (a) chupons and (b) fan-branches, points from 0 to 3 being awarded, based on vigour of regeneration.
3. Recent capsid damage on (a) chupons, (b) fan-branches and (c) pods.
4. Recent damage to the canopy caused by die-back from old cankers.
5. Other damage.
Points from 0 to 3 were awarded for records 3, 4 and 5 according to the severity of damage.
6. Flushing, points 0 to 3 awarded according to vigour of flush.
7. The number of pods removed at each four-weekly harvest. These were sub-divided according to the presence or absence of capsid damage. Pods removed because of rodent damage, or black-pod disease or other defects were included in the records.
8. Capsids were counted but not removed.

The total pod yield of each plot was also recorded.

Capsid counts declined rapidly on all treated plots during the first two to three months after treatment began. Meanwhile counts on the untreated plots were increasing to a peak in October, and this was followed by a slight fall in numbers in November and December and an even higher peak in January, after which the numbers fell steeply again. The initial control of capsids, which was established during the early treatments, was followed by a further decline under the continuous treatments which, in order of merit, were B, A, D and C. Spot treatments allowed some increase in numbers but in treatment E counts remained at less than 8 per cent. of those for the untreated plots. Dusting (Treatment F) was the least successful treatment; counts of capsids on the dusted plots rose to more than 18 per cent. of those on the untreated plots.

Damage to the canopy was assessed by observing dead leaves appearing as the result of capsid attack, all such leaves being removed after each monthly assessment. In the untreated plots the maximum damage was recorded in December and January. The results of damage assessment on the treated plots compared closely with the capsid counts, treatments B, A and D giving excellent control with less than 1 per cent. of the damage recorded on G plots. Treatments C (2 per cent.) and E (2.7 per cent.) were only a little less effective. Once again dusting was inferior to all liquid treatments (9.9 per cent.).

No effects on yield were expected, except perhaps at the end of the season. It was therefore disturbing to find that the yields from untreated plots were much below those for the treated plots. This result is in part due to the very low yields obtained on all three G plots in one of the three areas. The writer suspects that the results are spurious and this view is supported by the fact that the 'influence' of treatment on yield was very marked as early as eight weeks after treatment began. As yield is assessed by counting the number of pods removed from the trees at each four-weekly harvesting it is obvious that these early records are based on pods which had set two to three months before any insecticide was applied, and are therefore most unlikely to show any effects of treatment. Harvesting at intervals of less than four weeks was not possible, and it is reasonably certain that on at least two occasions, at the peak of the crop season, ripe pods had been removed from treated plots between experimental harvesting dates. Farmers whose plots received no insecticidal treatment might be less inclined to co-operate in such matters and this could have given rise to the anomalous results obtained, though this explanation cannot now be confirmed or checked.

The experiment has now been handed over to the Department of Agriculture, Western Region, Nigeria.

BALANCE SHEET

AS AT 31st MARCH 1957

WEST AFRICAN COCOA BALANCE SHEET AS

LIABILITIES

	£	s.	d.	£	s.	d.
SURPLUS ACCOUNT				2,849,887	2	6
CONTRACTOR'S DEPOSIT (Refundable)				6	0	0
DEPRECIATION FUND—						
Motor Vehicles	2,867	19	5			
General Equipment	4,188	16	6			
				7,056	15	11

(Sgd.) J. LAMB, *Director*.

(Sgd.) HYWEL LL. PUGH, *Secretary*.

£2,856,949 18 5

We have audited the above Balance Sheet of the West African Cocoa Research Institute as at 31st March, 1957, according to the best of our information and

Accra,

7th August, 1957.

RESEARCH INSTITUTE

AT 31st MARCH 1957

ASSETS					£	s.	d.	£	s.	d.
BUILDINGS—										
Value at 31st March, 1956	..	..	..	..	337,469	17	4			
Additions during year	..	..	..	..	3,516	8	9			
					340,986	6	1			
Less Amounts written off	..	..	..	..	340,986	6	1			
FURNITURE AND EQUIPMENT—										
Value at 31st March, 1956	..	..	..	..	32,338	6	6			
Additions during year	..	..	..	..	2,516	10	6			
					34,854	17	0			
Less Amounts written off	..	..	..	..	34,854	17	0			
DEPRECIATION FUND—										
Post Office Savings Bank—Deposit	..	..	..	..	3,954	5	9			
Bank of British West Africa, Limited—Deposit					3,102	10	2			
								7,056	15	11
SUNDRY DEBTORS—										
Staff Advances	..	..	..	..	11,964	17	0			
Nigerian Government	..	..	..	..	36	10	0			
West African Inter-Territorial Secretariat	..	..	..	..	163	0	0			
Duty Refund	..	..	..	..	8	6	3			
								12,172	13	3
STORES AT COST—										
Timber	..	..	..	..	631	16	11			
Maintenance	..	..	..	..	2,671	7	6			
								3,303	4	5
INVESTMENTS—at book value								2,677,352	16	7
(Market value £2,265,545 14s. 11d.)										
CASH—										
In Hand—Imprest Account	..	..	..	..	200	0	0			
Bank of British West Africa, Limited—										
Koforidua	..	..	..	7,407	9	0				
Ibadan	..	..	..	9,343	12	8				
					16,751	1	8			
Crown Agents—Joint Miscellaneous Fund	..	..	..	..	140,000	0	0			
—Current Account	..	..	..	..	113	6	7			
								157,064	8	3
								£2,856,949	18	5

Institute with the books and vouchers of the Institute and have obtained all the information and attached hereto, this Balance Sheet sets forth a true and correct view of the financial position explanations given to us and as shown by the Books of the Institute.

(Sgd.) CASSLETON ELLIOTT & CO.

Auditors.

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